TO BE PUBLISHED 27 MAY 1959

Forest Products Research 1958

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DEPARTMENT OF
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DEPARTMENT OF
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FOREST PRODUCTS RESEARCH 1958

Report of the
Director of Forest Products Research

LONDON
HER MAJESTY'S STATIONERY OFFICE
1959

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STATEMENT ON THE FOREST PRODUCTS RESEARCH STEERING COMMITTEE

In place of the Forest Products Research Board, a small Steering Committee has been set up to be responsible for the Laboratory's research programme. The Committee is a committee of the Research Council, is empowered to appoint sub-committees to advise on different aspects or sections of the Laboratory's work and has the following composition:

B. K. Blount, Esq., C.B., D.Phil.Nat., F.R.I.C. (*Chairman*)

H. Douglass, Esq.

F. Y. Henderson, Esq., C.B.E., D.Sc., Director, F.P.R.L.

L. J. Cardew Wood, Esq., B.Sc., A.C.G.I., M.Inst.C.E., M.I.Mech.E., A.F.R.Ae.S.

H. Wooldridge, Esq., O.B.E., B.Sc.

R. Edmonds, Esq. (*Secretary*).

The Steering Committee held its first meeting in October 1958 and its first report will cover the period 1st October, 1958, to 31st December, 1959.

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REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR 1958

General

At the beginning of the year, following a decision by the Research Council, the responsibility for much of the industrial work in certain fields of the Laboratory's work was transferred to the Research and Development Committee of the Timber Development Association, together with the associated advisory services. This has resulted in a progressive reorientation of the programme, which is not fully reflected in the present Report, largely owing to the rounding-off of projects already in train, and meeting commitments already accepted. There will be noted, however, a significant decrease in the work on exotic timbers, and a large increase in the work for the Forestry Commission, with whom a yet more extensive joint programme is in hand. In the general programme of research increasing emphasis is laid on the more fundamental work which should appropriately be done by a national laboratory and should underlie subsequent technological advance.

In its collaboration with the Forestry Commission, the Laboratory will shortly be entering the field of pulping research on home-grown timbers, and arrangements have already begun to re-deploy resources in staff and equipment and to adapt buildings for the provision of a laboratory to undertake both technical and fundamental pulping research.

STAFF

It is with great regret that we record the death of Ronald C. Fisher, B.Sc., Ph.D., F.R.S.E., on 23rd October, 1958. Dr. Fisher was the officer in charge of the Entomological Section from its inception at Princes Risborough in 1926 until the day of his death, and was an acknowledged authority on the biology of wood-destroying insects.

BUILDINGS AND EQUIPMENT

The extension to the Entomology building was completed during the year and equipped to provide insecticide and biological laboratories as well as additional space for records storage.

The new canteen and lecture hall has been completed and was taken over in November.

VISITS ABROAD

The Officer-in-Charge of Timber Mechanics represented the United Kingdom at the Fourth Wood Technology Conference of the Food and Agriculture Organisation of the United Nations, held in Madrid in April 1958. He presented a progress

report of the work of the Study Group concerned with Veneer, Plywood and Other Glued Veneer Constructions, and contributed to the general discussions of reports by other Groups in the several fields of wood technology.

Personal contacts with specialists in all branches of wood technology from other countries were renewed and the many discussions of problems of mutual interest proved to be of considerable value.

In June 1958, a senior officer from the Woodworking Section attended as a delegate the First International Sawmilling Congress, organised by the Fédération Nationale Belge des Scieries, at Namur, Belgium. In the Section of the Congress dealing with technical matters, he presented a paper on "Some Problems of Softwood Sawmilling in Great Britain".

The Congress included visits to Belgian machine manufacturers and to the Laboratoire Forestière at the University of Louvain, where it was possible to gain an insight into the woodworking research being done in Belgium.

PUBLICATIONS AND RECORDS

As well as the Annual Report for 1957, new Stationery Office publications issued during the year include the second edition of the textbook "Decay of Timber and its Prevention", two bulletins and *Special Report* No. 13 "The Longitudinal Permeability of some Hardwoods and Softwoods". The last-named discusses the variation in permeability along the grain of different woods, describes the work carried out in the determination of this property, and gives results for about a hundred species. *Bulletin* No. 42 is the fourth report in the series "The Strength Properties of Plywood". It gives an analysis of the test data accumulated in previous investigations and discusses stress values suitable for use in design calculations for a number of wood species when used in plywood. *Bulletin* No. 43 "Experiments on the Treatment of Redwood Sapwood by Dipping" describes tests carried out to determine the absorption, penetration and concentration of solvent type preservatives obtained in the sapwood of redwood (*Pinus sylvestris*) by dipping and steeping for various periods.

Revised editions of four leaflets were also published through the Stationery Office during the year, and 26 papers were issued through the scientific and technical press. Details of these are given in Appendix II.

In addition to the above, 19 reports were duplicated for limited circulation, eight being on the subject of composite wood.

Programme of Research

WOOD STRUCTURE

STUDIES IN COMPARATIVE ANATOMY

In recent years it has become increasingly evident that studies in wood anatomy can help in solving problems of botanical classification. Two examples of this type of work are the study of the timber of *Piptadenia* and some allied genera, referred to in last year's report (p. 5) and now published(1), and a paper discussing the anatomical structure and taxonomic status of *Pseudosindora palustris* which has been accepted for publication by the Linnean Society of London(2). Other work in this category has been confined to studies of the timbers being included in the identification keys referred to below.

IDENTIFICATION OF TIMBERS

The reduction in the volume of advisory work has made it possible to expedite the revision of the Laboratory's microscope key to the identification of hardwoods. This has involved checking the original observations by examining specimens acquired during the last 20 years or so and scrutinizing relevant literature published in the same period. The list of timbers included in the key has been extended to cover species of economic importance in the United Kingdom. The terms and definitions have been amended where necessary to conform with the recently published "International Glossary of Terms used in Wood Anatomy". Work on the important botanical families *Leguminosae* and *Meliaceae*, which has now been completed, has involved extensive bibliographical research and the critical examination of hundreds of sections.

During the year a second edition of the Laboratory's lens key to hardwoods (*Forest Products Research Bulletin* No. 25), published in 1952, has been called for, necessitating a thorough revision to incorporate the results of relevant research and experience over the last six years. The atlas of photomicrographs (*Bulletin* No. 26), the companion volume to the lens key, has also been reprinted this year and the opportunity has been taken to improve the quality of some of the plates and to make minor textual amendments.

Some progress has been made with the revision of *Bulletin* No. 22, Identification of Softwoods.

COLLECTION OF TIMBER SPECIMENS

The Laboratory's working collection of hand specimens, which is one of the most extensive in the world, provides the essential material for research on the comparative anatomy of timbers and on methods of identification. The exhibit collection comprises a comprehensive selection of boards and panels and an assortment of specimens illustrating peculiarities, defects and other special features. As in previous years a considerable amount of time has necessarily been devoted to the work of classifying and cataloguing the specimens which are continually being received and generally keeping the collection in order.

By courtesy of the Director of the Royal Botanic Gardens, Kew, a selection of specimens from the well known exhibit collection of timbers formerly housed in the Orangery at Kew has been handed over to the Laboratory. Specimens have also been received from the Norwegian Forest Research Institute at Vollebek, from the Forest Research Institute, Ibadan, Nigeria, and from the Forest Products Laboratory, Madison, U.S.A., and have been incorporated in the collection. In addition, over a thousand specimens from Brunei and nearly four hundred from North Borneo have been received but have not yet been catalogued.

FACTORS AFFECTING THE STRUCTURE AND QUALITY OF SOFTWOODS

In accordance with the decision to undertake more work on the general properties of home-grown timbers, further consideration has been given to the factors affecting the anatomical structure and related properties of softwoods as grown in this country. Further evidence has been obtained, both from this Laboratory's investigations and from those of other research workers, of the influence of ring age on the structure of wood. It is common knowledge to wood anatomists that the dimensions of cells at any height in the tree tend to increase from the inside of the stem outwards, particularly in the central core known as

"juvenile" wood. It has been found that the wall thickness of the summer wood tracheids in certain softwoods also increases with distance from the pith. Where there is a pronounced contrast between spring wood and summer wood, the trend is for both density and proportion of summer wood to increase as well (see Plate 1). Progressive changes in sub-microscopic structure and in chemical composition have been demonstrated also and it is becoming more and more apparent that ring age or distance from the pith is responsible for a larger part of the variation in structure and technical properties than was formerly realised. Failure to take the age effect into account has led to false conclusions on such questions as relations between conditions of growth and the quality of the timber. It is desirable that the practical implications of the phenomenon should be more widely appreciated and steps have been taken, through various channels, to bring them to the notice of timber technologists and foresters[3, 4, 5].

There is a growing realization that variation in the structure and technical properties of a timber may be due as much to the mixed genetical constitution of forest stands as to conditions of growth. Stock for breeding purposes needs to be selected with due regard to the character of the wood as well as the external features of the tree; moreover it is necessary to know the extent to which timber properties of selected trees are passed on to their progeny and how far it is feasible to breed for particularly desirable timber properties. During the year plans for research on these lines in co-operation with the Forestry Commission have been under active consideration.

A NEW METHOD OF DETERMINING THE DENSITY OF WOOD SAMPLES

With the co-operation of the Isotope Division of the Atomic Energy Research Establishment, Harwell, work has been continued on the development of a method of determining density on small wood samples by the use of β-rays. Tests have been made on a series of species having wood of uniform texture and covering a range in air-dry density of 0·1 (balsa) to nearly 1 (East African olive). This density range was chosen to correspond with what is likely to be encountered in the spring wood and summer wood of softwoods which are to be the subject of further intensive studies at the Laboratory. The use of even-textured timbers permitted accurate density determinations to be made on sizeable samples with the assurance that such observations were representative of the small portions subsequently assessed by the radiation method. The β-ray absorptions showed a regular relationship with density and confirmed that the method is basically sound. This procedure has been adopted as a means of calibrating the experimental apparatus.

Some time has been spent in testing different radio-active sources and in arranging suitable collimation of the beam so as to minimize the effect of secondary radiation and render the method suitable for studying the variation in density within individual growth rings. By using a small but intense source, portions of the growth ring only 0·5 mm wide can be examined. The density, determined in this way, shows close agreement with estimates made by more conventional methods.

A report on this work is being prepared for publication.

TESTS FOR HEARTWOOD

Supplementary work has been completed on the effect of fungal attack on the effectiveness of the benzidine test for distinguishing between sapwood and heartwood in pine. Difficulty has arisen in the manufacture of benzidine and

there is some uncertainty about future supplies of this reagent. For this reason tests have been made on an allied substance, ortho-tolidine, which has been found to differentiate between sapwood and heartwood in a similar manner to benzidine. These results have been incorporated in the report on the main investigation which has now been published[6].

SEASONING

KILNS AND KILN SEASONING

The seasoning properties of many species have been investigated during the year and the large kilns have been used for seasoning consignments of abura, Indian rosewood, Douglas fir, English oak and Sitka spruce. The Sitka spruce was 6 in. in thickness and of aircraft quality. Drying was often a lengthy process but the final quality of the seasoned material was in every case satisfactory. In the test series on the seasoning properties of home-grown softwoods, loads of Japanese larch, European larch, grand fir, noble fir and western hemlock have been dried.

THE KILN DRYING OF OBECHE

A series of tests was carried out in the miniature kilns to study the effect, on the drying rate and final condition of $1\frac{1}{8}$ in. obeche boards, of using much lower humidities than had previously been thought necessary in order to prevent splitting with this timber. It was found that the boards, even when green, could be exposed to humidities as low as 5 per cent without suffering appreciable degrade and with the advantage that they dried more quickly, shrank less and had a brighter final appearance than when dried at the high humidities employed hitherto. It would probably be impossible in most existing commercial kilns to establish and maintain an inlet humidity as low as 5 per cent without making improvements to the ventilation arrangements, but the test results indicated that if these were made and the drying were conducted in a good reversible forced-draught kiln with inlet air conditions of 180°F and, say, 15 per cent relative humidity it should be possible to dry a full-sized load satisfactorily within two days, which is little more than half the time required to dry the same material with conventional treatment. Thin boards of obeche are doubtless exceptionally tolerant of extremely low humidities and there are probably few other timbers which would withstand such severe treatment without splitting. It is not unlikely, however, that some other of the less refractory species, particularly in the smaller sizes, would react favourably to lower initial humidity conditions than have so far been thought necessary.

KILN DESIGN

Tests in the kiln of novel design with horizontally positioned fans have been completed and it has been shown that the arrangement provides for very good air movement with a relatively small power demand. An article giving details of the kiln design and of the results of air movement tests has been published[7].

One of the miniature kilns has been modified so as to be truly reversible, automatically controlled and capable of operating satisfactorily over a very wide range of air temperatures and humidities. This now can be said to be a first-class unit for the carrying out of almost any line of research on the behaviour of wood when drying.

SHRINKAGE STUDIES

The effect of drying conditions on the shrinkage of Scots pine has been studied and a new method has been evolved for ensuring the slow drying of very small sections at high temperatures. The method consists essentially of sealing the specimens hermetically inside holes in a block of wet wood which is itself dried under controlled conditions in a kiln.

Matched sets of six tangentially cut specimens were dried (*a*) as rapidly as possible, and (*b*) in a period of about six days at temperatures of 0°, 25°, 55°, 85° and 100°C respectively. The total shrinkages from green to zero moisture content were recorded and are given in Table 1. Although the results obtained in previous experiments had shown that temperature and speed of drying markedly affected the shrinkage of beech, the present set of readings would suggest that apart from a slight decrease in shrinkage induced by rapid drying at a high temperature, the factors of temperature and speed of drying had relatively little effect upon the shrinkage of Scots pine. This finding is consistent with the general observation that Scots pine is most tolerant of temperature in kiln seasoning.

Table 1. *The shrinkage of small sections of Scots pine dried at two different rates and at various temperatures.*

Temperature °C	Tangential shrinkage per cent		Temperature °C	Radial shrinkage per cent	
	Very fast drying	Slow drying		Very fast drying	Slow drying
0	8·1	7·4	0	3·3	3·3
25	7·4	8·0			
55	7·1	7·5	55	3·0	3·0
85	6·8	7·3			
100	6·8	7·8	100	2·7	3·1

SWELLING PRESSURES

Exploratory tests have been started to determine the pressures exerted by 1 in. cubes of dry beech when restrained either in a radial or tangential direction and wetted on the four exposed faces. The cubes were clamped between metal plates, one of which was connected to a pressure measuring device, and, with the rate of wetting obtained, it was found that the pressures recorded rose to a maximum after about six hours when the average moisture content was of the order of 30 per cent. The pressure then gradually decreased and a certain amount of "permanent set" was induced although a large degree of recovery occurred when the blocks were released from restraint. It was interesting to note that although the strain induced in the radially held blocks was about half that in the tangentially held ones, the pressures exerted were about the same, partly in consequence of the fact that the value of Young's modulus is roughly twice as large in the radial as in the tangential direction.

DISTORTION EXPERIMENTS

A further series of tests, to determine the effect of mechanical restraint on distortion but using keruing as the test material, has been completed. The effectiveness of imposing restraint in reducing distortion has been assessed by expressing the distortion of the restrained samples as a percentage of that of matched control samples, and it was found with keruing, as with beech and African mahogany, that restraint is a great deal more effective in reducing "cup" than in reducing longitudinal distortion. The results also confirmed that the beneficial effect of restraint increases with an increase in the temperature at which drying is conducted, and showed that a further significant reduction in distortion can be achieved by exposing the samples to a temperature of 100°C for 12 hours before removal of the restraint. Some of the keruing samples were dried to the final moisture content of 10 per cent from an initially green condition, others from an initial moisture content of about 20 per cent. A greater reduction in cup was observed on the samples which were initially wetter, but the effect of initial moisture content on the reduction of longitudinal distortion was not so clearly marked.

RATE OF MOISTURE ABSORPTION

Samples of beech, Scots pine, iroko and East African olive in thicknesses of $\frac{1}{2}$ in., 1 in. and 2 in. respectively have been conditioned to a moisture content of about 10 per cent in the 45 per cent humidity room and these then have been moved into the room conditioned to a humidity of 90 per cent. The rate of moisture pick-up has been measured and at the same time the rates of increase of the dimensions of their cross-section have been determined. The results have yet to be analysed.

MOISTURE-PROOFING EFFICIENCY OF SURFACE COATINGS

The efficiency with which a number of materials, commonly used for the finishing of wood, reduce the rate of moisture absorption, has been measured by exposing treated beech panels to controlled humidity conditions. The results show that some wood finishes are relatively permeable to water vapour. The highest efficiency recorded in the series was obtained when the samples were given three brush coats of a phenolic resin varnish.

THE ACCURACY OF THE RESISTANCE-TYPE MOISTURE METER

On some hundreds of samples of a wide variety of species, a comparison has been made between the readings obtained with a resistance-type moisture meter and the moisture content as determined by the standard oven-drying method. Before being tested, all the samples were brought to steady and uniformly-distributed moisture contents by long exposure under constant atmospheric conditions. On many of the samples, the meter readings differed appreciably from the moisture contents determined by oven-drying and the magnitude of the difference varied with the species and also from piece to piece within a species. The results of the investigation have been published in an article[8] which drew attention also to other possible sources of error in the instrument readings.

THE MOISTURE CONTENT OF FRESHLY FELLED CONIFERS

As part of the joint research programme with the Forestry Commission, an examination has been started of the moisture content variation in freshly cut softwoods. A preliminary scheme designed to show the variations which exist within a tree, between trees and between sites, in Sitka spruce and Scots pine, has been completed and extension of the work is under consideration.

WOOD BENDING

SOLID BENDING

Experiments have been carried out to determine the bending properties of nine home-grown softwoods and five tropical hardwoods as well as of home-grown ash from various localities. The softwoods tested, which included species such as Douglas fir, Japanese larch and Sitka spruce, were found to possess intrinsic bending properties superior to those of many of the tropically grown hardwoods, but their gross properties and hence their commercial value were markedly and adversely affected by the presence of knots.

Experiments carried out on hickory (*Carya* sp.) confirmed that this species possessed good bending properties but the bent specimens appeared to be very prone to check in drying and setting and the forces required for the bending operation were found to be considerably greater than, say, those for the bending of similar specimens of beech.

A study of the reaction of certain bending woods such as ash, elm and other timbers to radio-frequency heating for softening has been made and an article on the findings prepared for publication.

It has been known for some time that steamed and heavily compressed bending woods such as beech are rendered flexible in the cold, semi-dried state, but little is known concerning the influence that factors such as moisture content, degree of compression, etc., might have on the final properties of the material. In order to investigate the significance of these factors a method of producing the compressed wood in quantity but in short lengths was developed and a number of large blocks of compressed beech have now been made from which small samples will be cut and prepared for testing.

LAMINATED BENDING

The limiting radii of curvature of thin laminae obtained from six hardwoods and seven softwoods have been determined and extensive data on the bending properties of laminae from clear redwood ranging in thickness from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. have been examined. From such tests it has been established that quarter-sawn softwoods bend to a significantly smaller radius than matched slash-sawn material but that diffuse porous hardwoods, such as beech and birch, bend to a smaller radius when slash-sawn. The method of conversion appears, however, to have but little effect upon the bending properties of laminae cut from ring porous hardwoods such as oak and ash.

PLYWOOD BENDING

Further attention has been paid to the problem of setting African mahogany plywood to shape, and time devoted to devising suitable methods of pressing and moulding plywood to various degrees of double curvature. Standard bending tests have been completed on $\frac{3}{16}$ in. plywood made from *Bosquiea phoberos* and also from *Khaya anthotheca*. A report has been prepared embodying all data obtained to date on the bending properties of various species of plywood.

MISCELLANEOUS TESTS

At the request of industry, special tests have been undertaken to devise methods of bending and setting to shape tapered and turned back feet for chairs and whangee canes for umbrella handles.

TIMBER MECHANICS

FACTORS INFLUENCING THE STRENGTH PROPERTIES OF WOOD

(a) *Sylvicultural and Anatomical*

Studies of the relationships between the strength properties of wood and natural defects, habitat and inherent characteristics, have continued throughout the year. In particular the testing of home-grown softwoods, in co-operation with the Forestry Commission, has provided much information on their quality and on site and provenance variation.

The investigations have included tests on a large number of species of conifer on both the clear material and on the large-size member with its natural defects. The tests on the clear material have provided basic data on all strength properties of 17 consignments taken from 10 species and these have been analysed in detail. Consignments of Norway spruce from the west of Scotland and North Wales, Douglas fir from the north of Scotland, Japanese larch from South Wales and the south of Scotland and Corsican pine from East Anglia have been graded and tested in a typical joist size to determine their strength and allied properties. All data have been examined and comparisons have been made with material from similar species tested previously. The results of these investigations and the analysis of data have assisted materially in the planning and design of the future research programme on the native softwood species.

The consignment of Corsican pine from East Anglia has also been sampled to investigate a reputed tendency to brittleness. Because of this, the species is not often used for certain purposes. A consignment of Scots pine from the same area has been sampled in a similar manner to afford a comparison between the two species in this respect. The investigation is continuing.

Several consignments of colonial hardwoods have been investigated during the year. Basic data on strength and related properties have been obtained for East African olive, keruing, sapele, dark red seraya, and red seraya. Work on these hardwoods is diminishing and with the testing of outstanding consignments of white seraya and African mahogany the project will be terminated.

The investigation into the properties of English ash reported in the Annual Report for 1957 (p. 13) is continuing. Results of tests on three consignments of ash from South Wales, South Devon, and Kent have been analysed. In all instances the difference between these consignments for all the strength properties in the green and air-dried conditions and for most of the kiln-dried tests is small; thus it appears that the factor of habitat has little significance. An important finding is that kiln-drying procedures using a normal schedule for ash, as compared with air-drying, produces no degrade in the wood. So far no definite evidence is available concerning the effect of other variables on strength, but it is significant that there are indications of the stronger material being more highly lignified than the weaker. Additional consignments of ash from other areas in the United Kingdom have been tested and an analysis of all the data is now in progress.

(b) *Variability*

The sampling of the structural softwoods, redwood and Canadian western hemlock, for studies in variability in strength within the species has continued. To date 38 consignments of redwood and 10 of western hemlock have been tested. This completes the projected programme for western hemlock and the data from the investigation are being analysed. The results indicate that although the average values for the physical and mechanical properties are similar to those obtained from Canadian tests on western hemlock, they show a much greater variability. As measured by the coefficient of variation the material in the present investigation was as much as 50 per cent more variable in some properties. This difference is fully reflected in working stresses derived from the two sets of figures. A detailed report of the investigation on western hemlock is being prepared for publication.

(c) *Temperature*

The investigation to study the influence of temperature on strength properties of timber has continued. Additional tests have been made, using the double-walled testing chamber developed for this work, on Douglas fir, ash and balsa at temperatures of — 190°C and — 75°C, as well as normal temperatures. The strength properties so far investigated include maximum bending strength, modulus of elasticity, and total work, compression parallel to the grain, and shear strength. Experiments have been made on both green timber and matched material conditioned to approximately 12 per cent moisture content.

The results of these tests indicate that there are very appreciable increases in most strength properties as the temperature is reduced. The increase is greatest in compression strength, somewhat less in bending strength properties and least in shear strength.

The investigation has been extended to examine the effect of temperature on tensile strength parallel to the grain. A second double-walled cabinet has been designed as well as an elongated type of specimen which can be gripped outside the chamber, for the determination of this property. Results so far suggest that the tensile strength is much less affected than most other strength properties by decrease in temperatures below normal. This work is continuing.

(d) *Rate and Duration of Loading*

The long-term loading experiments initiated in 1954 have been extended to study the influence of duration of loading with reference to plastic flow and creep under constant load. Test apparatus as illustrated in Plate 2 has been designed for use in humidity rooms.

A first series of experiments using noble fir beams with a cross-section of 2 cm × 3 cm, and a span of 60 cm, is in progress. The ultimate bending strength of the control specimens has been determined and tests have also been carried out to determine the point at which plastic flow begins under rapid cyclic loading. Matched specimens for the long-term loading tests have been loaded in the apparatus, under constant conditions of temperature and humidity, to percentages of their ultimate bending strength varying from 90 to 15, and deflections are being recorded at regular intervals to enable time-deflection curves to be prepared.

The experiments to investigate the behaviour of nailed joints under continuously applied constant load, commenced in 1957, have continued. A series of different types of nailed joint are under load. These include three sets of two-member single shear joints in three species, covering the range of density for

softwood joints, one set of three-member double shear joints in redwood, all of which are fabricated using a large gauge nail, and also two sets comprising two-member single shear and three-member double shear joints in redwood, which are assembled with a small gauge nail. All of these sets of test joint have an applied load corresponding to their respective permissible loads. In addition the effect of overloading of a joint is being examined with one set of single shear joints in redwood made up with a large gauge nail. For comparative purposes similar nailed joints matched with those under long-term loading have been loaded to failure in tests of short duration.

(e) *Biological Agencies*

An investigation to examine the effect of staining by the blue-stain fungus (*Lasiodiplodia theobromae*) on the strength properties of ramin has been completed. Tests on both inoculated and control specimens have shown that progressive staining causes insignificant losses in bending strength and modulus of elasticity (stiffness). There is, however, a marked reduction in toughness in the early stages of attack and as the staining increases over a longer period, this strength property is more seriously affected. Thus ramin, even if blue-stained, can be safely used for most purposes where the property of toughness is not of primary importance. A report on this work has been published[9].

A study has also been made of the relationship between progressive decay by an active soft rot organism, *Chaetomium globosum*, and the strength of wood. Two series of experiments have been carried out, one to examine the effect of the decay on the bending strength and toughness of wood and the other to afford a comparison with both brown and white rots, particularly in respect of resistance to impact. The results of the investigation indicate that the ultimate bending strength of beech is not affected significantly until a dry weight loss of from 2 to 3 per cent occurs. Brashness in the wood develops rapidly with progressive decay and there is a reduction of over 30 per cent in this strength property when the loss in dry weight reaches 8 per cent. A reduction in the property of toughness is, however, immediate and becomes most marked—about 50 per cent—for a loss in dry weight of about 2 per cent. The effect of the soft rot on the resistance to impact is comparable to that of both the brown and white rots, *Coniophora cerebella* and *Polystictus versicolor*. All three fungi produce an immediate serious reduction in this strength property. A report is being prepared for publication.

THE STRENGTH OF COMPOSITE WOOD ASSEMBLIES

(a) *Plywood*

The general investigation for the determination of the basic strength properties of a standard plywood construction made from different species of wood has been terminated. It is believed that all those species likely to be of value to British plywood manufacturers have been included in the 38 species investigated. Strength data for 18 species have been analysed and stress values suitable for use in design calculations have been determined for them. A bulletin presenting the results of this work together with an outline of current methods used in the design of structural elements in plywood has been published[10].

(b) *Laminated Construction*

During the past year further progress has been made towards the completion of the bulletin on laminated timber construction. The results of earlier investigations on the influence of initial curvature on the strength of curved beams and

on the strength of horizontally and vertically laminated straight beams have been summarized for inclusion. Experiments have been completed on 70 beams and 160 short columns comprising four and eight laminations of home-grown Scots pine, these latter being graded according to tentative rules for the stress grading of wood for use in laminated members. The results of these tests have enabled relationships to be established between knot area ratios and compression strength and between the second moment of knot areas and bending strength. Further experiments are in progress with members of Douglas fir to examine if these relationships are dependent upon the species of wood.

The size and frequency of the strength-reducing characteristics, knots and inclined grain, which occur in samples of Scots pine and Douglas fir have also been measured. These have been expressed in a numerical code and an analysis is being made of the probability of occurrence of defects in any section of a laminated member. On completion of this analysis it will be possible to derive working stress values for laminated timber and to determine the significance of using stress graded material in members comprising various numbers of laminae.

A study of the geometry of construction of a plywood shoe beam has been made at the request of the London Transport Executive. This type of beam is mounted under an electric train, carrying the shoe for the pick-up of electric current. One of these shoe beams had fractured during a minor derailment and the Transport Executive wished to investigate the possibility of increasing its strength. Any increase in strength had to be achieved without changing the dimensions of the beam since any alteration in overall size would necessitate a major modification. After consultation with the Transport Executive and the plywood manufacturers, a different geometry of construction for the shoe beam was suggested. Experiments have been completed on prototypes of the modified shoe beam and these give a 50 per cent improvement in the critical strength property.

MISCELLANEOUS

(a) *Strength of Boat and Engine Bearer Frames*

Comparative tests have been carried out at the request of the Director of Naval Construction on three types of laminated timber corner frames and three types of engine bearer frames. One of each type in the two groups was of the same design as those used in the construction of wooden naval vessels and the others were modified units aimed at improvements in design. The tests on the laminated corner frames gave inconclusive results, the performances for two types of loading likely to be encountered in service being different. The standard type of engine bearer frame was a complicated, built-up structure of lattice beams; the proposed modifications were fabricated using heavy plywood web beams. The thickness of the plywood web differed in the two alternative types of frame. The tests in these engine frames indicate with all three types an adequate margin of strength for the vertical loads they are intended to carry, and the frames with the solid plywood webs are appreciably stiffer than the standard type with lattice beams. This is an advantage where it is desirable to have good alignment of all engine shafting.

(b) *Strength of Timber Connector Joints*

The supplementary series of experiments on toothed-plate timber connector joints outlined in the Annual Report for 1957 (p. 15) have now been completed. The purpose of these experiments was to provide data on the effect of the moisture condition of the wood on the strength of the joints.

The results of these experiments are being analysed and considered together with data from all previous tests to derive suitable permissible loads for toothed-plate timber connector joints. A final report on the work is being prepared.

WOODWORKING

THEORY OF CUTTING

Research on the theory of cutting has continued using both the high-speed "whirling arm" and the low-speed rectilinear apparatus, but being confined in both cases to the simplest example of wood cutting, namely, a straight cut of uniform depth, parallel with the grain of the wood.

On the high-speed machine, which has been fitted with an improved cutter-head having magnesium-alloy beams for its strain gauges, an extensive series of tests covering cutting angles from 10° to 40°, and speeds from 1000 to 7500 ft/min, at various chip thicknesses, has been completed. Sycamore (*Acer pseudo-platanus*) has been used for these tests, but before the results can be evaluated further tests are required to obtain data on the dimensional changes of the chip as it is cut, for correlation with the force measurements already made. These chip-measurement experiments are now in progress.

Improvements have been made in the instrumentation of the low-speed apparatus. In the measurement of forces on an apparatus of this type, the requirements of sensitivity to very small forces, and of high rigidity in the specimen holder, are in conflict. The stiffness adopted in this instance for the light-alloy beams (whose deflection under load is the parameter actually being measured) is of the order of 300 kg/mm, so that the depth of cut will not be upset by deflections in the apparatus.

The extremely small movement obtained in the apparatus could not be measured satisfactorily by gauges of the wire-resistance or inductance types, and "mechano-electronic" transducers are used. In these, the deflection is applied to move one electrode of a thermionic valve, causing a change in the anode resistance of the valve which can be made apparent as a change in d.c. voltage in a bridge-circuit and amplified to operate a chart recorder. With this system a reading of one millimetre on the chart can represent a force of 2·5 g.

Two measuring channels are provided to record forces parallel with and normal to the direction of cutting, and investigations of the effect of cutting angle and depth of cut have already been made. Figs. 1 and 2 show the forces recorded when cutting beech. In Fig. 1 it can be seen that the force parallel with the surface of cut increases directly with chip thickness. However, the force normal to the surface, shown in Fig. 2, while varying linearly with chip thickness, increases at the smallest cutting angles, and decreases at angles of 30° and 40°.

Other variables whose effects can be investigated on this apparatus are density, moisture content and grain orientation. Measurements at much smaller chip thicknesses will also be possible. A view of the apparatus is given in Plate 3.

PLANING INVESTIGATIONS

A report on the investigations carried out on the commercial four-sided planing machine and reported in last year's Annual Report (p. 18) has been issued[11].

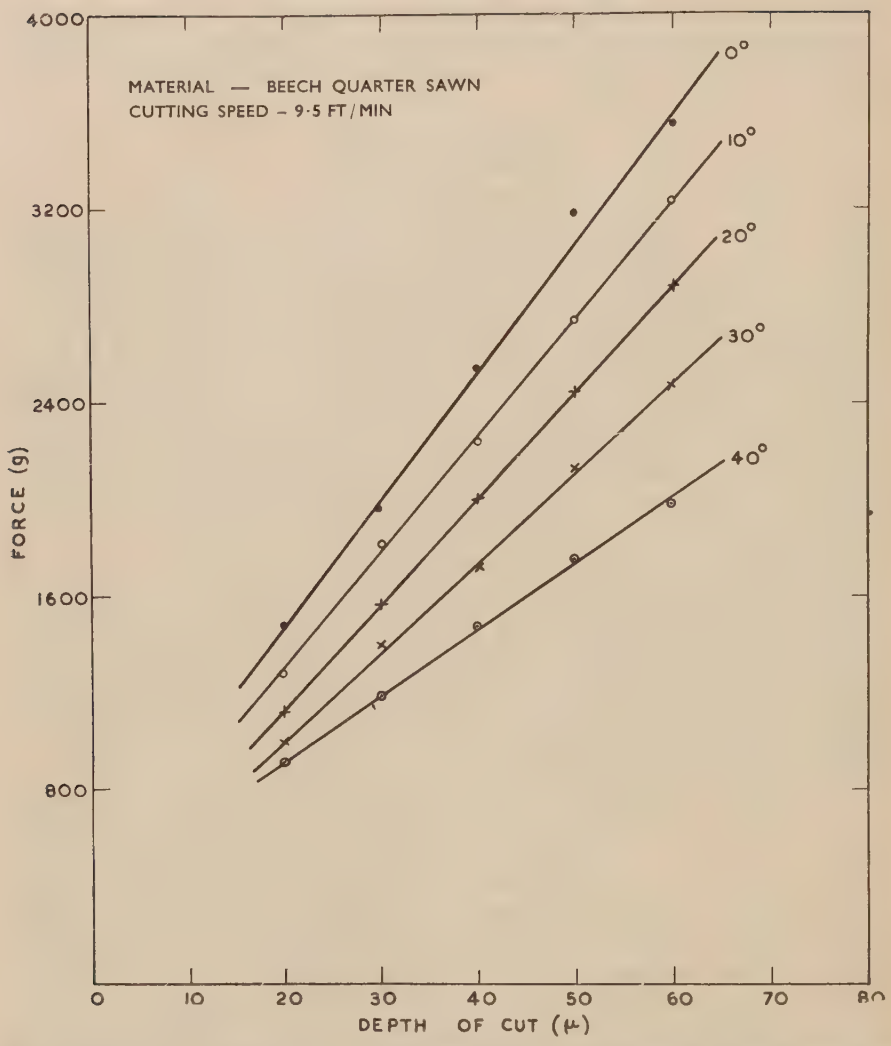


Fig. 1. Relation of depth of cut to cutting forces. Force parallel to surface of cut.

HANDSAWS

The information obtained from the experiments described in the Annual Report for 1957 (p. 20) has been used to construct a testing machine capable of operating a handsaw under conditions approaching those found in manual use. The machine consists essentially of two parts, a frame for holding the handsaw, which is pivoted at one end on two pairs of widely spaced parallel links, and a clamp for holding a timber specimen which is reciprocated by a crank and shaft on a rod placed under and parallel with the handsaw blade. In operation, the saw is lowered on to the reciprocating specimen of wood and cuts through it at a rate dependent on the counter-balance weights applied to the linkage system and on the angle that the links make with the horizontal. The machine is so constructed that the links are inclined slightly above and below the horizontal during the early and late stages of the cut respectively. This

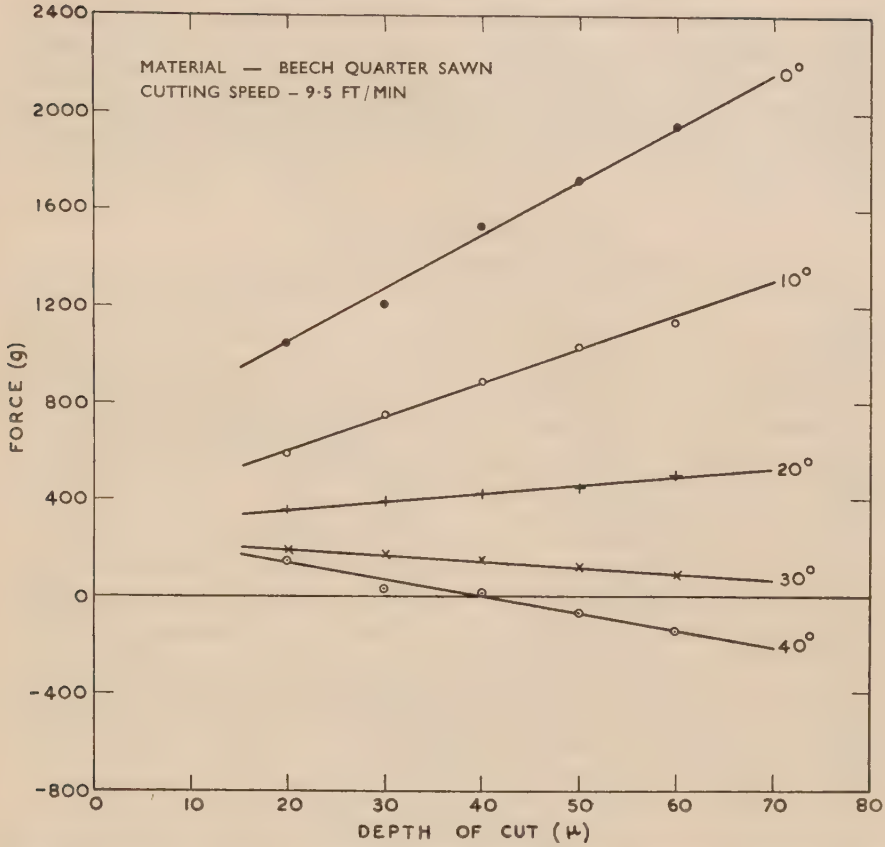


Fig. 2. Relation of depth of cut to cutting forces. Force normal to surface of cut.

difference in their attitude ensures that the saw follows normal practice by cutting more heavily after it has become buried in the wood. An interesting feature in the operation of the machine is an electro-magnetic device which raises and disengages the handsaw teeth from the wood, as is normal practice in manual operation, during the return or non-cutting portion of the stroke. The performance of a handsaw fitted to the machine is assessed by counting automatically the number of strokes required to cut a certain depth of wood.

A programme of research planned to provide data on all the factors affecting the performance of handsaws is in progress. Experiments so far have been concerned with the effect of hook and bevel angles on ease of cutting and quality of sawn finish. Handsaws having six teeth per inch, with hook and bevel angles ranging from 5° to 25° and 10° to 40° respectively, have been employed for ripsawing and cross-cutting kiln-dried redwood and beech. In the cross-cutting of the redwood, an increase in hook and bevel angle caused an increase and a decrease respectively in the number of strokes needed to cut the same area of wood, but there was no practical difference in the performance of handsaws having teeth with 5° and 10° hook and 10° to 40° bevel angle. In the other experiments, the ripsawing of redwood and the cross-cutting and ripsawing of beech, the performance of the handsaws deteriorated with either increasing hook or bevel angle. The handsaw with 5° hook and 10° bevel always gave the optimum

performance in both operations, but except in the ripsawing of beech, there was no great difference in saw performance having 5° and 10° hook with 10° and 20° bevel angle. An indication of the effect of hook and bevel angle on the performance of commonly used handsaws is given in Table 2. For the purpose of comparison the number of strokes needed by the saws with 5° hook and 10° bevel has been equated to 100 irrespective of the class of sawing operation and species of timber sawn.

Table 2

Effect of hook and bevel angle on the performance of handsaws

Hook angle Bevel angle		5° 10°	5° 40°	15° 10°	15° 40°
Species	Operation	Relative number of strokes to cut a wood specimen of uniform size			
Redwood	Cross-cutting	100	100	135	110
	Ripsawing	100	266	152	713
Beech	Cross-cutting	100	128	190	245
	Ripsawing	100	404	314	589

LOG CROSS-CUTTING

A number of experiments have been carried out, as part of the joint Forestry Commission programme, to supply information on the relative merits of teeth of different design on two-man log cross-cut saws.

SAWMILLING SURVEY

As the large softwood forests planted in this country from 1918 onward mature, new sawmills will be needed, and some existing ones will be reorganized also to handle the new timber crop. In order to be in a position as this occurs to offer advice and assistance to sawmillers and to the Forestry Commission, a project on sawmilling has been initiated.

As a beginning, a survey of the existing literature on sawmilling—the types and sizes of mills and the performance of their machinery—has been made, particular notice being taken of points likely to be applicable to British conditions and of interest to home sawmillers and the Forestry Commission. In addition, visits have been made to a number of the more up-to-date sawmills typical of various types of layout.

The preliminary findings of the survey[12] merely clarify the various types of sawmill layout and machinery currently in use and indicate the general regime of operation to which each is suited. No specific recommendations which could be of general application to sawmilling in this country are made: in fact the primary finding of the survey and the visits is that no one type of mill or equipment can be singled out as the best for universal use in this country.

An extension of the survey to a more intensive evaluation of individual layout types of mill, which might allow a more accurate discrimination to be made between layouts whose relative advantages seem at present to be only marginal, is proposed. This would make possible the positive recommendation of a particular type of mill for a given set of conditions.

WOODWORKING PROPERTIES

Full-scale tests have been carried out to determine the machining and nailing properties of the following home-grown kiln-dried softwoods: Scots pine, Norway spruce, Douglas fir, Japanese larch, European larch and Corsican pine.

Similar tests have also been made on red seraya and keruing (North Borneo) and East African olive (Sudan).

COMPOSITE WOOD

STUDIES OF GLUES AND GLUING

(a) *Durability of Adhesives*

Long-term tests. Between 1942 and 1947, large batches of standard three-ply gap and close-contact joints had been made for long-term ageing tests[13]. The material had been stored under constant conditions of 25°C and 60 per cent relative humidity to maintain a moisture content of 12 per cent and batches had been mechanically tested in the dry state at pre-arranged intervals over periods of at least ten years. From the results the percentage joint strengths retained were evaluated.

Very few of the sets kept their full initial value, and between and within brands of any one type of adhesive the joint strength fell by varying amounts. The cold-setting ureas for example, showed an average retention of 65 per cent over 69 sets, but for individual sets, the figures ranged from 40 to 95 per cent. A further criterion in the assessment was whether the joints retained the minimum initial strength requirement of the appropriate B.S. Specification. The results with all types of adhesive are given in Table 3.

Table 3

Decline in strength of standard glued joints stored indoors for ten years

Type of glue	Temperature of use °C	Percentage failing load retained		Total number of sets	Number above B.S.S. of 10 years
		Average	Range		
Resorcinol resin .	15	95	80–100	10	9
Phenolic resin .	145	90	70–100	10	10
	15	80	60– 95	27	21
Urea resin . .	100	90	75–100	10	10
	15	65	40– 95	69	18
Casein . .	15–95	85	70–100	11	9
Animal . . .	15–80	85	70– 90	5	3

While these figures record the facts, in interpreting them it must be remembered that the adhesives tested were those available 10 to 15 years ago and were not necessarily even then recommended by their makers for their longevity.

H.M.S. Hornet. The study of the behaviour of glued wood products in light naval craft continues in the motor gunboat originally maintained for the Laboratory by H.M.S. *Hornet*, but now by H.M.S. *Dolphin*. A report[14] after

seven and a half years of observations gives an account not only of the material installed in the boat for experimental purposes, but of the boat itself, upon the fabric of which systematic examinations and tests are made.

Tests in Nigeria. With the closing of the Ministry of Supply's Tropical Testing Establishment in Nigeria, work on the assessment of assembly glues has had to terminate, and a final report[15] for the five and a half years has been issued. This experiment used the "ash tray" test-piece first described in the Annual Report for 1951 (p. 21), made with animal, casein, urea, phenolic and resorcinol glues and exposed at Port Harcourt and at Kano (rain-forest and savannah climates, respectively) and in England, where tests were also made in the Laboratory's Tropical House. All glues remained sound in storage at 25°C and 60 per cent relative humidity, as did the phenolic and resorcinol resins under full exposure to weather in both countries. In other environments, the performance of the remaining three types of adhesive is indicated in Table 4.

Table 4

Durability of assembly glues in England and Nigeria

So = Sound Det = Deterioration F = Fail

Environment	Locality	Animal glue	Casein glue	Urea resin
Living room or office	Princes Risborough .	So	So	So
	Port Harcourt—Town .	So	So	So
	Jungle .	F	F	So
	Kano	F	Det	Det
Unheated ventilated shed in open	Princes Risborough .	F	So	So
	Port Harcourt—Town *.	F	F	Det
	Jungle*.	F	F	Det
	Kano† . . .	F	Det	Det
Tropical House Princes Risborough	Wet room* . . .	F	F	So
	Dry room† . . .	So	So	So

* and † Show corresponding situations.

In general, deterioration was greater in Nigeria than in the corresponding environment in England. The Laboratory's Tropical House (particularly the Dry Room) proved to be milder to continuously exposed material than were the natural conditions. This is probably attributable to the absence of any rainy season effects.

Series V and C. In Series V, the most recent of the long-term durability tests on plywood adhesives, additions have been made to the glues selected in 1954, and there are now 31 of 10 different chemical types, including such experimental resins as the epoxide. In the corresponding Series C for assembly glues, there are 26 of 9 types. Other new adhesives are incorporated as they become available. The identification of chemical types and the definition of certain characteristics of the glues have been simplified by a new code prepared at the Laboratory's request by the British Plastics Federation. A report[16] on Series V and C gives the results with the 1954 material over three years and the initial test data for the adhesives added later.

With the plywood glues exposed to weather, the results follow expected lines, namely that only phenolic types are likely to be successful. For testing adhesives based broadly on urea resin, the plywood is alternated at six-monthly

intervals between the Dry Room and Wet Room of the Tropical House (see the 1951 Annual Report, p. 25). This cycle, which gives an equilibrium moisture content range of 5½ to 17 per cent, has been adopted as a standard for assessing glues under interim conditions, i.e. where wetting by rain and dew and irradiation by sunlight do not occur. Over three years, this treatment has produced a considerable amount of degrade; none of the plywood panels has shown separation at the glue lines, but the bond quality as assessed by the knife test has fallen seriously. The reasons for this unexpected result are being investigated.

In Series C, the tests on assembly glues using the proof-block sample, the Tropical House results are similar, but in the outdoor exposure, some phenolic-based resins have failed and some urea glues have shown no degrade. That the former should fail is contrary to earlier experience, as is the survival for so long of some of the ureas. The epoxy glues are variable in their performance, but it seems unlikely that they will withstand full exposure to weather for long periods.

(b) *Gluing Technique and Testing Methods*

For the attainment of an adequate glue bond between two pieces of wood it is usually considered necessary for the two surfaces to be held together under a positive pressure until the adhesive has set. In practice the level of bonding pressure varies widely. For instance, in plywood manufacture, pressures of between 100 Lb/in.^{2} and 300 Lb/in.^{2} are in common usage while, in veneering and assembly work generally satisfactory joints are to be obtained with pressures of as low as 15 Lb/in.^{2}. It became clear, however, from a study of the available literature[17], and from some preliminary experiments that for any investigation on the function of pressure, the pressure could not be studied alone, but only in conjunction with the properties of a particular adhesive and with an understanding of the nature and roughness of the surfaces to be bonded. The investigation was planned, therefore, to determine the effect and relative importance of the following four factors in the bonding of wood:

(*a*) the bonding pressure,
(*b*) the nature of the surfaces to be glued,
(*c*) the type of glue, and
(*d*) the bonding temperature.

Six levels of bonding pressure between 25 Lb/in.^{2} and 200 Lb/in.^{2} were used with two types of surface, a peeled veneer and one obtained by planing and lightly sanding a composite-grained lamina. Tests showed that the variation in thickness of the peeled veneer was between two and three times that of the one obtained by planing and sanding. Two glues, a close-contact and a gap-filling urea formaldehyde were used at two setting temperatures, 25°C (77°F) and 95°C (203°F).

The procedure was to make 6 in. square samples of 3 × 0·125 in. veneers laid alternately at right angles under each combination of the four factors and to test the resulting plywood by the knife test of B.S. 1455: 1956. The bonding pressure could be measured with certainty and accurately maintained throughout the pressing time. Fourteen samples were made with each combination of variables, a total of 672 samples and 1344 glue lines and the results were examined by the analysis of variance.

This preliminary investigation has shown that pressure is important with both adhesives at the higher temperature and with the close-contact glue at the lower one, but the function of pressure is not only to bring the two surfaces together and thus help the adhesive to span the gaps between them, but also to

promote the wetting of the unspread surface by the glue. The roughness of the surface has little effect on the adhesion within the limits employed, the smoother planed material giving generally lower bonds than the rougher peeled veneer. An account of this work has been issued[18].

In last year's Annual Report (p. 21), mention was made of a method for testing the resistance of P.V.A. adhesives to a sustained load. Although developed primarily for the thermoplastic glues, it has been applied to the thermo-setting group, and animal, casein, urea-formaldehyde and resorcinol-formaldehyde types are being subjected to a sustained load in a controlled atmosphere of 25°C (77°F) and 60 per cent relative humidity; approximately 12 per cent moisture content in wood. The applied load of 105 lb is approximately 30 per cent of the failing load when tested at a constant rate-of-strain of 0·2 in. per minute. The experiment has now been in progress for two years without any joint failures occurring.

Adhesives based on natural or synthetic rubber and known as contact or impact glues are now much used for sticking together a variety of materials, including wood, to itself or to plastic sheet. A brief survey of the wood-to-wood uses has been made with two brands of contact glue. Open assembly time (the period for which the two spread surfaces are allowed to lose solvent before being put together) must exceed a certain minimum for a joint to form at all, but can be much longer than the instruction sheets prescribe. In lap joints of the type used in B.S. 1204: 1956, failure occurs in the contact glue and not the wood, and the failing load increases from 300 lb in a few days to a steady value of about 500 to 700 lb in ten weeks. (Traditional wood glues have a failing load of 750 lb.) Wet strength in the cold water test is about one-third of the appropriate dry strength.

The two contact glues were tested for resistance to sustained loading in the manner devised for P.V.A. glues and described in the Annual Report for 1957 (p. 21). One failed within three weeks but the second remained unaffected at the end of a two-month period. Weathering tests are still in progress, but with this type of adhesive, high resistance appears to be unlikely.

DISTORTION OF PLYWOOD

In the Annual Report for 1957 (p. 22) an account is given of an investigation made to obtain a better understanding of the causes of distortion in plywood of balanced construction. This work has continued[19] with a study of the behaviour of distorted plywood after manufacture. Plywood samples 11 in. square and composed of three 0·064 in. veneers laid alternately at right angles were subjected to four different wetting and drying cycles, the amount of distortion and the moisture content being measured at each stage in the cycles. The results indicate that the amount of distortion increases proportionately as the moisture content departs from that immediately after pressing. The amount is independent of the type of moisture content cycle and of the previous history of the sample.

The work on the behaviour of distorted plywood of balanced construction is continuing with a study of the influence of the board construction and thickness. Generally, the thicker the plywood the smaller is the distortion but the make-up of the board can have a considerable effect on its subsequent behaviour.

DEFECTS IN VENEERED PLYWOOD

Last year's Annual Report (p. 23) told of progress in finding the underlying causes of the corrugations that can spoil the appearance of decorative veneer

laid on plywood. Further work is confirming that even small moisture changes after manufacture have considerable influence, as do even small lathe checks in the veneer forming the face or outer surface of the underlying plywood.

The elimination of lathe checks during peeling has been under study for some time and is complicated by matters such as over-stiffness of veneer and distortion in drying if the back is made too tight. A definition of veneer quality in quantitative terms is being sought.

During the peeling of a large diameter log previously heated to 85°C, a new cause of trouble was met. The process was carried out with the minimum stoppage time, and whilst most of the veneer was smooth and tight, that cut towards the later stages had a scuffed surface and a slack back—neither of which was attributable to log quality or to defective pre-treatment. None of the available manual adjustments of knife and nosebar would overcome the trouble, and the possibility that it was due to thermal distortion of these parts was investigated[20], the purpose being to find the extent of such movement, and even more important, their direction, so that remedial action could be systematically applied.

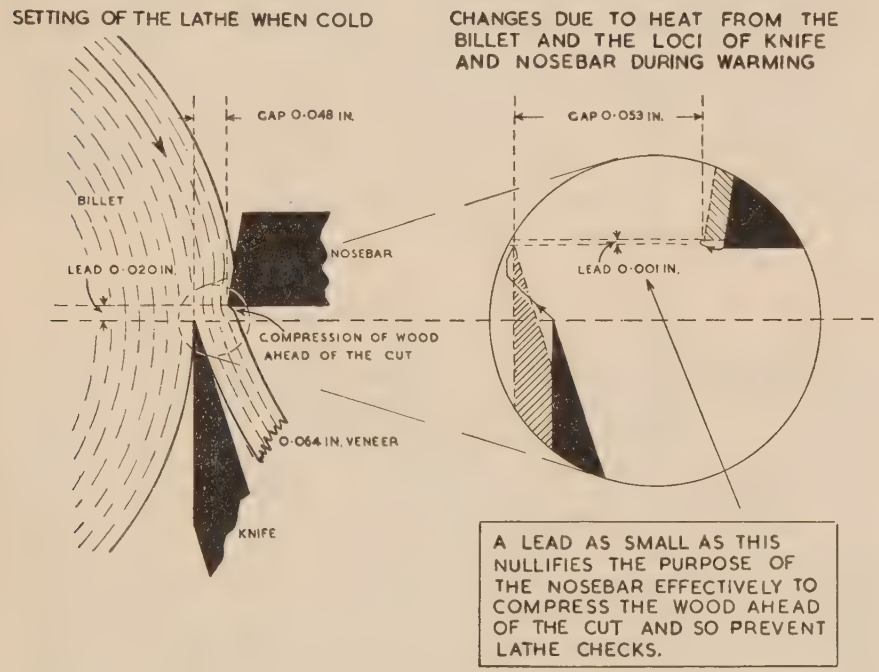

SETTING OF THE LATHE WHEN COLD
CHANGES DUE TO HEAT FROM THE BILLET AND THE LOCI OF KNIFE AND NOSEBAR DURING WARMING
GAP 0·048 IN.
GAP 0·053 IN.
BILLET
NOSEBAR
LEAD 0·020 IN.
LEAD 0·001 IN.
COMPRESSION OF WOOD AHEAD OF THE CUT
0·064 IN. VENEER
KNIFE
A LEAD AS SMALL AS THIS NULLIFIES THE PURPOSE OF THE NOSEBAR EFFECTIVELY TO COMPRESS THE WOOD AHEAD OF THE CUT AND SO PREVENT LATHE CHECKS.

Fig. 3. Effect of thermal expansion of a veneer lathe.

From a stiff beam bolted to the knife carriage trunnions, four dial gauges were fitted as in Plate 4 to indicate the horizontal and vertical movement of the knife and nosebar, at the mid-span of the lathe. Plate 4 also shows how the log was cut away to clear the gauges, which were zeroed with the machine in equilibrium with room temperature. A hot log was loaded, and observations made turn by turn whilst the lathe heated up. When the first log was spent, it was quickly replaced by another at the same temperature, and the tests continued without break. Sixty turns were cut from this second billet, and after about 20,

the horizontal movements of knife and nosebar ceased as did the vertical movement of the lathe, but the vertical creep of the knife continued until the end of the run. Fig. 3 shows the net result of these thermal distortions, which is to increase the gap a little (which may result in slack veneer) and to reduce the lead to the point where the nosebar cannot compress the wood sufficiently ahead of the knife to promote its proper cutting action. With these tendencies known, however, prior adjustment of lead can be made to meet conditions of long peels with hot logs.

CONDITIONING OF VENEERS

Basic investigations[21] have been made into the conditioning of veneer from the scattered moisture contents that obtain after it leaves the dryer to a precise figure applicable to plywood manufacture. The tests have so far been with veneers only 24 in. × 6 in. in size, but they show the order of times required for such work.

A small kiln was adapted to give a temperature range of 40 to 106°C with humidity controlled to give a moisture content of 9 per cent, and an air speed variable between 80 and 355 ft/min. After trials, standard conditions of 95°C, 76 per cent relative humidity and 180 ft/min were selected. Veneers of gaboon and khaya from 0·064 in. to 0·125 in. thick were brought to zero and 19 per cent moisture content respectively and to intermediate ranges, and then conditioned in the kiln to between 8 and 11 per cent. Fig. 4 shows typical curves for 0·10 in. gaboon, and indicates the spread of results at any particular time in terms of initial moisture content. The time required for conditioning depends on the range of moisture content that can be tolerated, but in any case this is a matter of 20 minutes to half an hour, and not one of days.

RADIO FREQUENCY HEATING

The ageing properties of glued joints cured under radio frequency heating is being investigated and results are now available for seven and a half years[22]. A laminated beech sample was employed with adhesives of the urea-, phenol- and resorcinol-formaldehyde types and with one animal glue. The force needed to separate each pair of laminates was measured after storage at 25°C (77°F) and 60 per cent relative humidity for periods of 0, ½, 1, 1½, 2, 3, 5 and 7½ years. The results indicate that joints set in 60 seconds by radio frequency heating generally behave similarly to those set at room temperature. Joints set in 10 seconds, however, have a slightly lower initial strength but their ageing properties are not impaired by the higher rate of setting.

The reason for the dependance of the initial joint strength on the rate of setting of the adhesive has now been investigated[23]. The performance has been assessed of various commercially available brands of synthetic resin adhesives, in B.S. 1204: 1956—type close contact joints, cured under radio frequency glue line heating. The setting times of the adhesives varied between 10 and 40 seconds. This experiment confirmed that some brands of adhesive, although satisfactory when set at room temperature, gave low failing loads under fast radio frequency heating. In glue line heating the adhesive is heated rapidly and selectively, owing to the large difference in radio frequency conductivity between the glue and the wood, and a high temperature is attained before the glue is cured. As the viscosity of the resin hardener mix usually decreases as the temperature is raised, the glue can become very fluid in the period immediately prior to gelling.

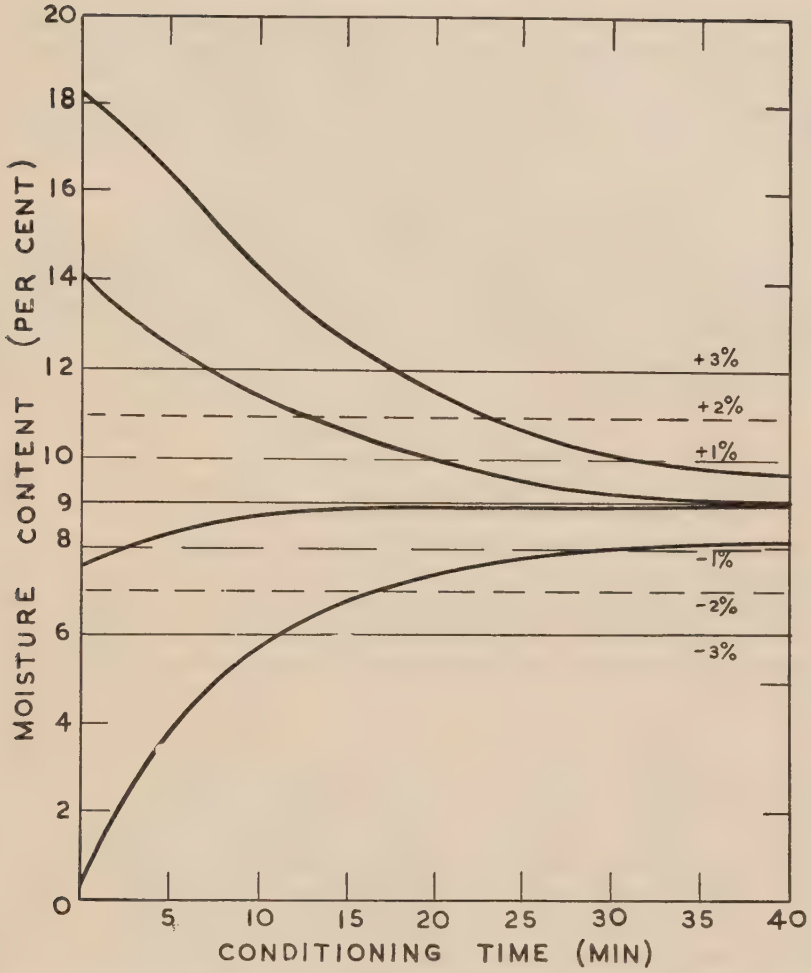


Fig. 4. The conditioning of 0·10 in. gaboon veneer showing the spread of final moisture content.

Temperature 95°C Relative Humidity 76% Air Speed 180 ft/min

During this transient stage in the setting process, the fluid adhesive is more easily absorbed by the wood and, if the joint area is small, squeezed out of the glue line. In both cases there may be insufficient glue left between the two surfaces to span the irregularities and ensure a good bond. The cause of the unsatisfactory bonds with some adhesives is thus due to a combination of three factors, firstly a comparatively long setting time which allows the glue to attain a high temperature before gelling, secondly a viscosity-temperature relationship such that the glue becomes very fluid at elevated temperatures and thirdly a radio frequency conductivity such that the glue heats up rapidly in a radio frequency field. An adjustment of these factors is mainly a matter of formulation but the reasoning is supported by the results of this experiment. For instance, an increase in bonding pressure improves the performance of the unsatisfactory glues. The higher the bonding pressure, the smaller the amount of glue needed to span the irregularities between the two surfaces and the greater the amount

of glue that can be allowed to leave the glue line without affecting the quality of the bond. An improvement in performance can also be achieved by adding up to 20 per cent of an amylaceous or inert extender, thus improving the viscosity-temperature characteristics of the glue and, in the case of the inert material, blocking the passages from the glue line along which the adhesive can escape into the wood.

THE COMPOSITE WOOD RESEARCH PANEL

Shortly after the last war, two informal industrial advisory panels, the Adhesive Makers' Panel and the Plywood Research Panel were formed and have met regularly to discuss the Laboratory's programme of research in composite wood. For some time their work has been converging, and it was therefore decided to amalgamate them. The new combined panel will be convened, with the same informal terms of reference, as the Composite Wood Research Panel.

WOOD PRESERVATION

THE EFFECT OF WATER IMMERSION ON THE PERMEABILITY OF TIMBER AND ON ITS TENDENCY TO BLEED AFTER CREOSOTING

An important problem in the preservation of pine poles is the exudation or bleeding of creosote which may occur when freshly treated poles are exposed to the sun. This has caused a good deal of trouble not only in this country but also on the Continent and in the U.S.A., and although steaming treatment and solvent vapour baths have been developed which can reduce this exudation to a certain extent no really satisfactory solution of the problem has yet been found.

The poles used in this country are usually of redwood (*Pinus sylvestris*) from Finland, Sweden and Norway. It has been found from experience that when bleeding does occur it is generally only with Swedish and Finnish poles and not with the Norwegian, and it has sometimes been suggested that this might be owing to the fact that in Norway poles are usually transported by floating, whereas in Sweden and Finland this method is not so generally used. Whether this is the explanation or whether there is an inherent difference in *Pinus sylvestris* grown in different regions has not, however, been established. During an investigation into the problem of bleeding carried out at the Laboratory some time ago it was confirmed that there is a marked difference between poles from Norway and other sources in their tendency to bleed. The Norwegian poles appeared also to be more permeable, which could account for the absence of bleeding, but no indication of the reason for these differences was found. The higher permeability of the Norwegian material was subsequently confirmed by gas flow measurements on samples from a few different consignments from each country (see Table 5), but unfortunately it was not possible to ascertain any details of their history between felling and arrival in this country. In continuation of this work experiments were planned to establish whether immersion in water was in any way responsible for this important difference in behaviour.

At about this time some interesting results were obtained during an investigation into the treatment of redwood lumber by dipping in organic solvent preservatives. The timber, which was selected from a large number of sources covering Sweden, Finland and Russia, absorbed preservative in two noticeably different ways. In about two-thirds of the material, penetration of the preservative into the sapwood was fairly small and quite regular but in the remainder it was much deeper and usually very irregular. This difference in behaviour did

not seem to have any connexion with the source of the timber. At first it was thought to be due to the presence of staining fungi, as these can cause an appreciable increase in the permeability of sapwood, and the surface of the more penetrable material was often coloured faintly yellow, but microscopic examination did not confirm this. It was also noticed that in the more permeable material the concentration of the preservative in the penetrated zone of the wood was not uniform, but showed pronounced radial streaks of high and low loading similar to those which are sometimes found in creosoted poles which bleed in longitudinal bands. It seemed possible that this difference in penetrability and the variation in the tendency to bleed might have a common explanation, and that this might lie in whether or not the material was floated or in some other aspect of its history between felling and treatment rather than in the origin of the timber.

Table 5

Permeability of the sapwood of redwood poles from different sources

Source	Permeability in $cm^3/s\ cm^2\ atm/cm$		
	Longitudinal	Radial	Tangential
Norway	880	8·3	2·4
	630	8·5	·8
*	17	·2	·004
Finland	31	·14	·002
	20	·51	·008
	19	·36	·006
	11	·17	·004
	11	·07	·002
Sweden	9	·04	·004
	3	·02	·001
AVERAGES			
Norway . . .	755	8·4	1·6
Finland . . .	18	·25	·004
Sweden . . .	6	·03	·002
RATIOS			
Norway . . .	126	280	800
Finland . . .	3	8	2
Sweden . . .	1	1	1

* Omitted from averages.

Experiments were therefore started some time ago to investigate the effect of water immersion on both the permeability of pine sapwood and on its tendency to bleed when creosoted. Home-grown Scots pine, which is the same species as redwood, was used for this work as it was more convenient to obtain freshly felled and of known history. Some 6 in. × $2\frac{1}{2}$ in. material was air seasoned directly after conversion and some matched samples were kept in the log pond for four months and then air seasoned. On treating with a solvent preservative as in the experiments mentioned above it was found that the samples which had been kept in the pond before seasoning absorbed about eight times as much

preservative as those that were seasoned directly after conversion. The penetration was much greater and showed a similar radial pattern to that obtained in Baltic redwood and described above. The permeability of the sapwood of the soaked and unsoaked material was also measured directly from observations of gas flow and the increase in each direction due to soaking was as follows:

Longitudinal . .	16 times
Radial . . .	9 times
Tangential. . .	3 times

Further experiments showed that pre-soaking resulted in almost the same increase in absorptiveness if the wood was rapidly kiln dried instead of air seasoned.

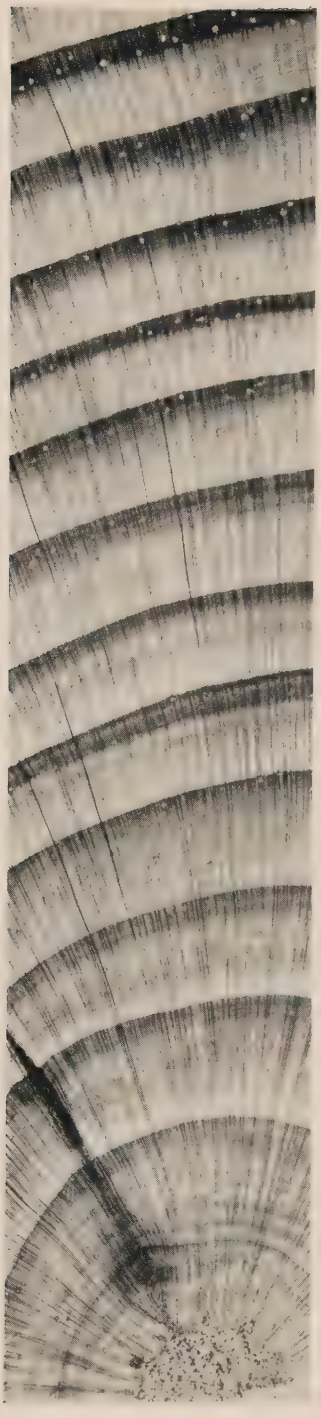
Soaking for the same period in tap water in the laboratory was found also to increase the permeability but not to the same extent.

To investigate the effect of soaking on bleeding, a number of 10 ft lengths of freshly felled Scots pine about 6–8 in. in diameter were obtained. Each of these was cut in two lengths, one of which was kiln seasoned immediately and the other kept in the pond for six months and then kilned by the same schedule. A slow, low temperature schedule was used to simulate fast air drying during the summer. The soaked and unsoaked pole lengths were then end-sealed and creosoted together by a Rueping schedule similar to that used for the commercial treatment of redwood poles. Both groups were clean on removal from the plant but on exposure to the sun all the unsoaked lengths bled profusely whereas the soaked samples remained quite dry throughout the several weeks they were kept under observation (see Plate 5). The freedom of the soaked samples from any tendency to bleed is emphasised by the fact that their average retention of creosote was much higher than that obtained in the unsoaked, namely 15 as compared with 10 lb/cu. ft, which would have aggravated any tendency to bleed they might have had.

It is evident from these experiments that the permeability of pine sapwood can be much increased by soaking in water before seasoning and the tendency of the wood to bleed after creosoting can be eliminated. There is a certain amount of direct advantage to be had from increasing the permeability of pine sapwood even though it is initially quite easy to impregnate but the indirect result, that of eliminating bleeding, is of major importance. The period of six months soaking in the above tests was fixed quite arbitrarily and it will be necessary to determine the minimum time that is necessary before it is possible to consider to what extent soaking is a practicable operation. This can best be done by investigating how the permeability changes during soaking and determining at what value the tendency to bleed disappears.

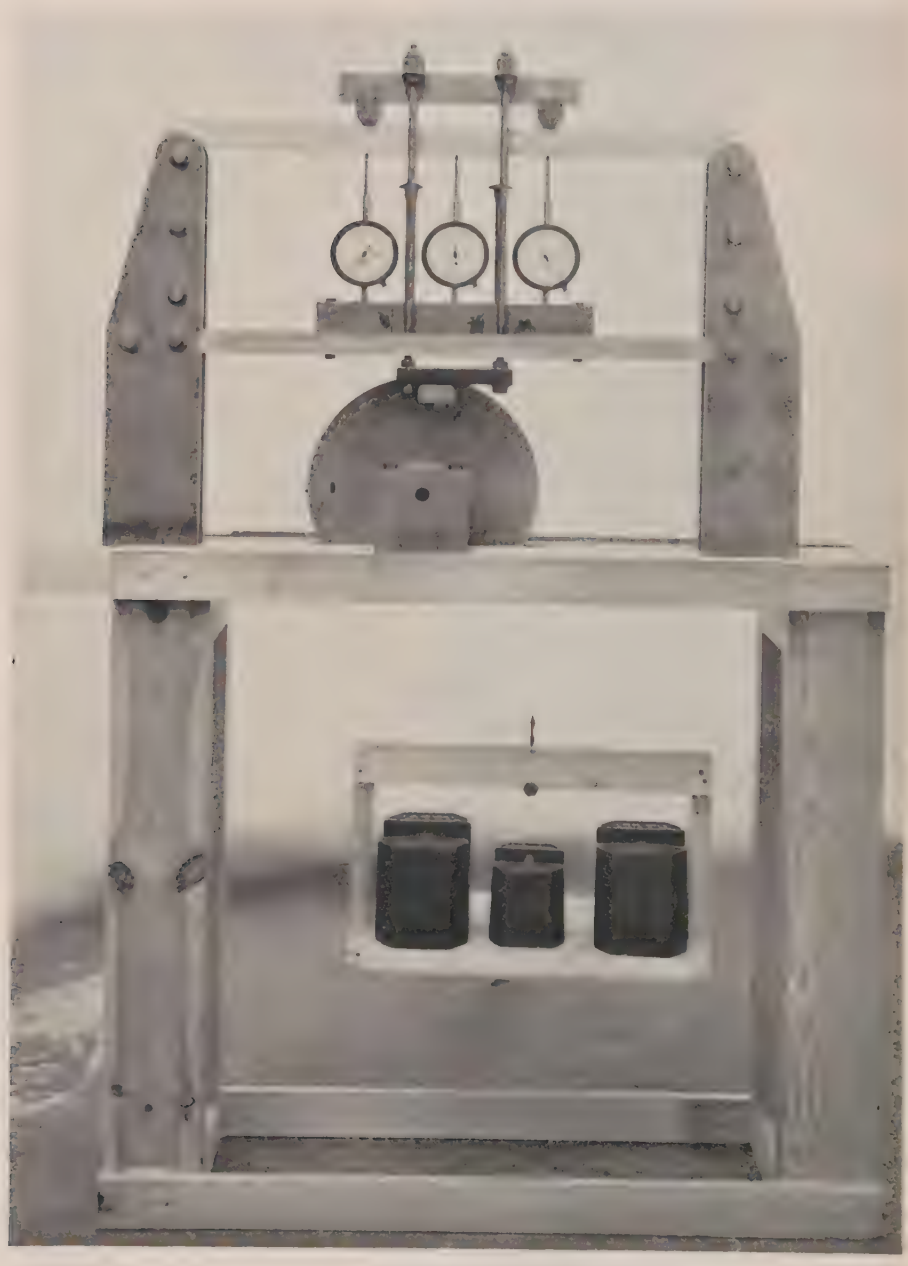
It is considered that the significance of the soaking operation lies in keeping the wood wet and if this is so it may be more convenient to do this by other means as, for example, by delaying barking. The changes brought about in the wood by soaking have not yet been established but it is thought they are primarily the decomposition and removal of cell contents probably by biological action and further work is to be carried out on this aspect of the problem.

Having established that soaking produces a large increase in the permeability of pine sapwood the next step was to find out whether it would do the same with other species which are inherently low in permeability and would benefit particularly from any increase. Three of the most important home-grown softwoods, namely Sitka spruce, Douglas fir and Japanese larch are of this type. Not only the heartwood but also the sapwood of these species is difficult or



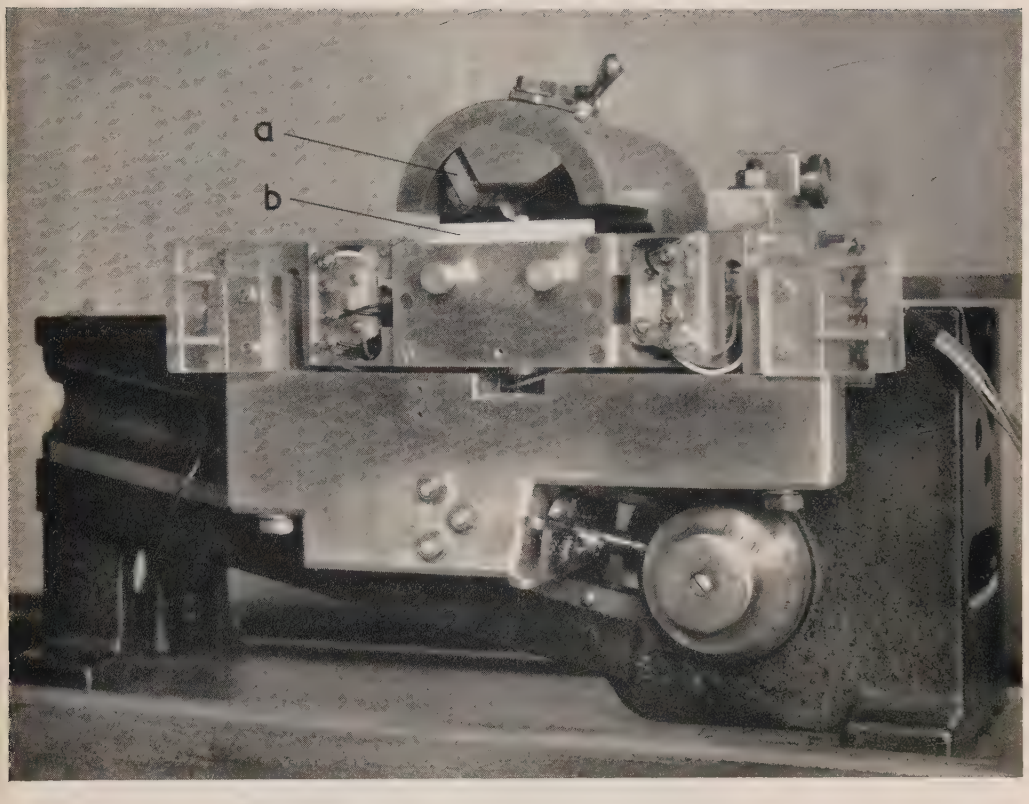
Cross-section of Scots pine showing change in structure from the centre of the tree outwards, notably the gradual increase in the density and proportion of summer wood during the juvenile period. Mag. $\times 4$.

PLATE 1



Portable apparatus for investigating creep.

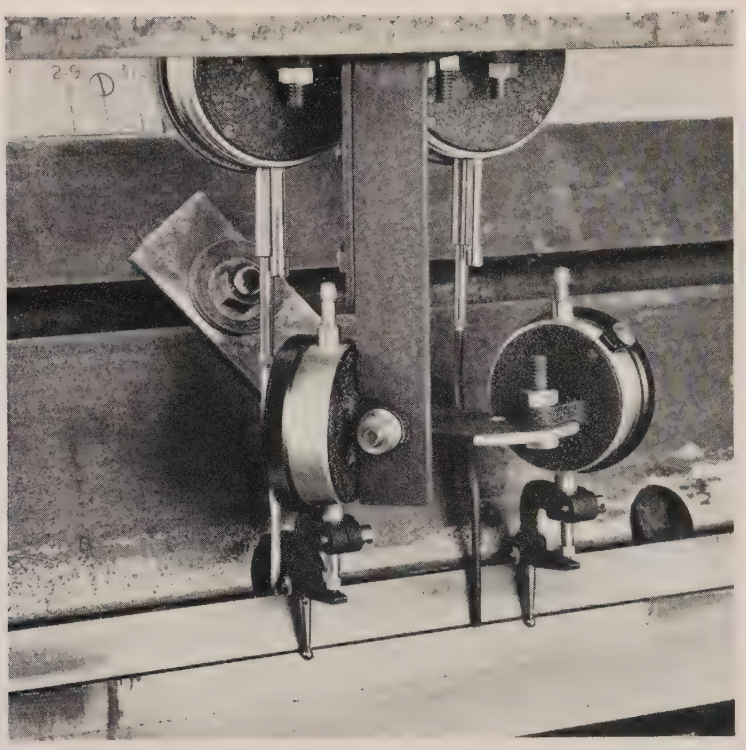
PLATE 2



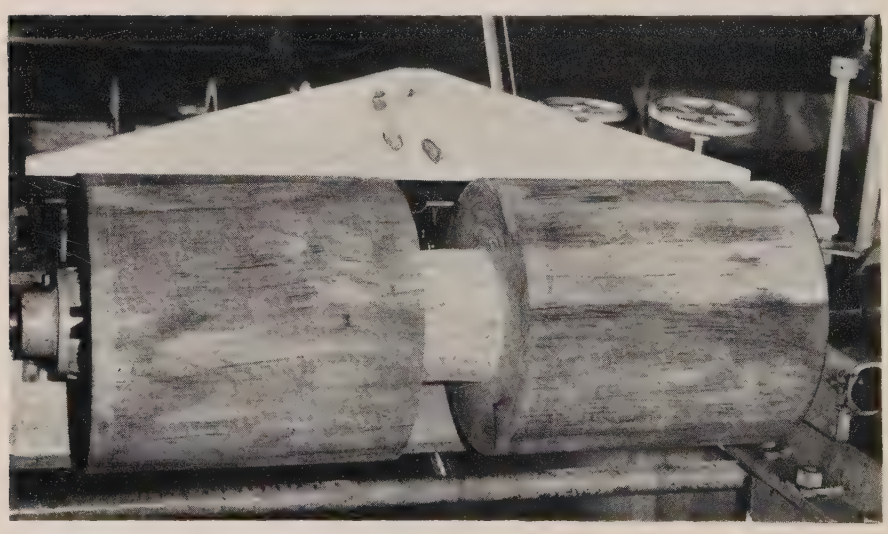
Apparatus for research on the theory of cutting at low speeds.

(*a*) Cutter and cutter head. (*b*) Wood specimen.

PLATE 3

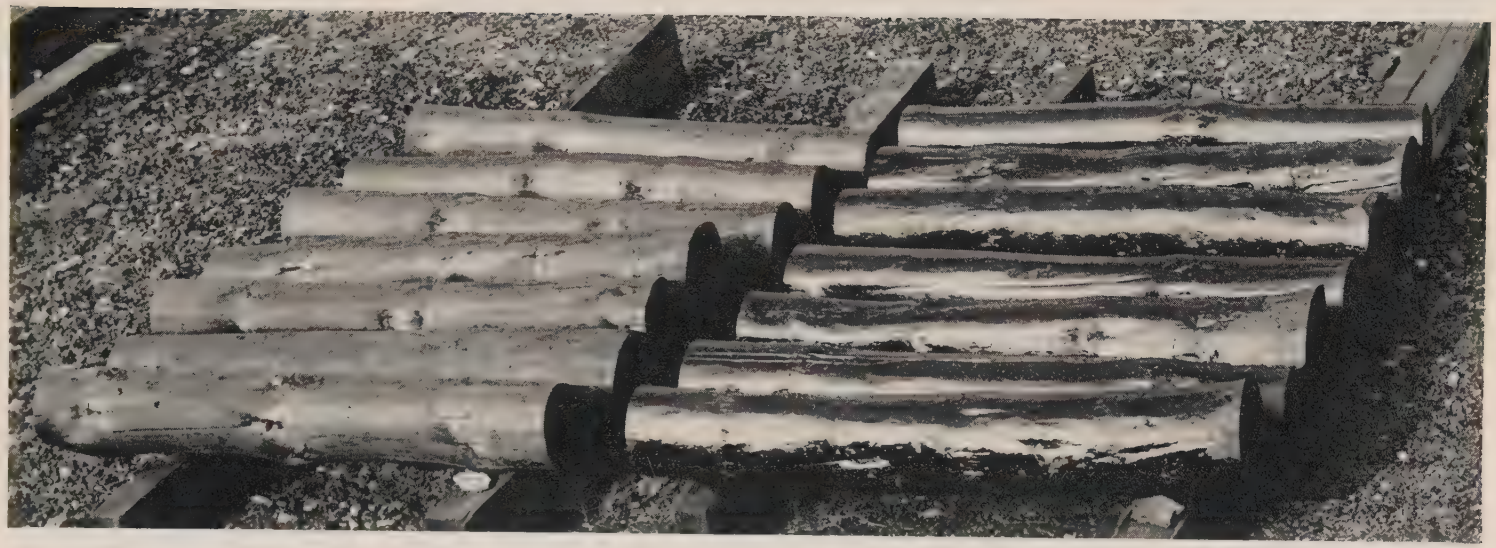


(A) Arrangement of dial gauges to detect horizontal and vertical movement of the knife and nosebar of a veneer lathe under actual cutting conditions.



(B) Log grooved to accommodate the gauges.

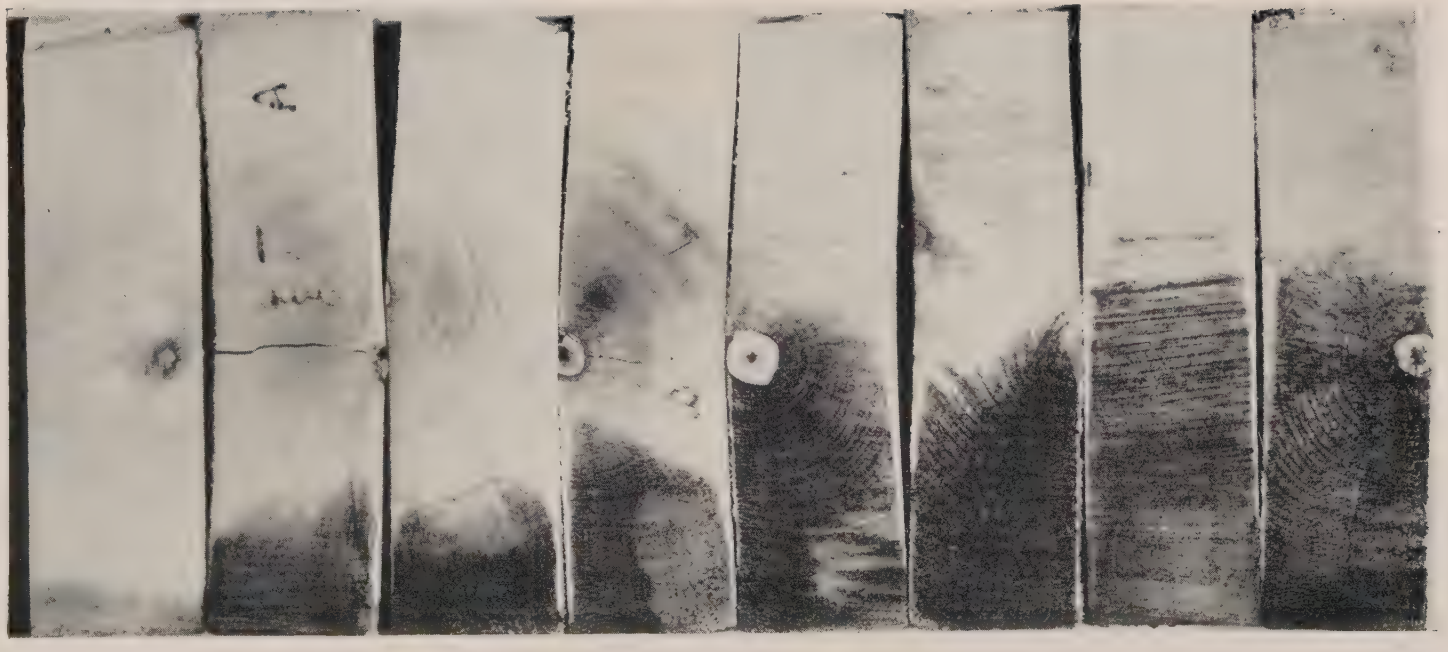
PLATE 4



Soaked *Unsoaked*

The prevention of bleeding of creosoted Scots pine by water storage before seasoning.

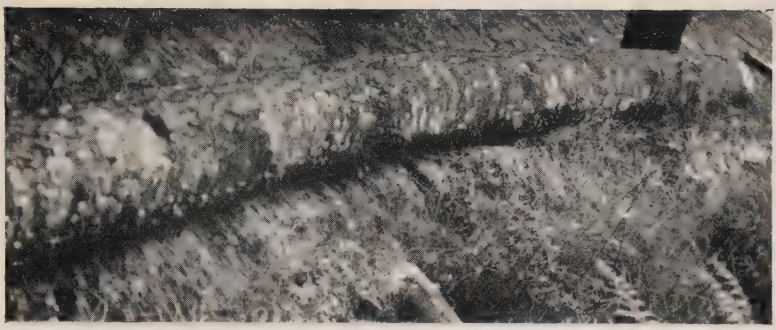
PLATE 5



7 12 16 23 33 41 56 68 days

Progress of staining by *Lasiodiplodia theobromae* across the grain of horse-chestnut. The samples were 7 cm. high.

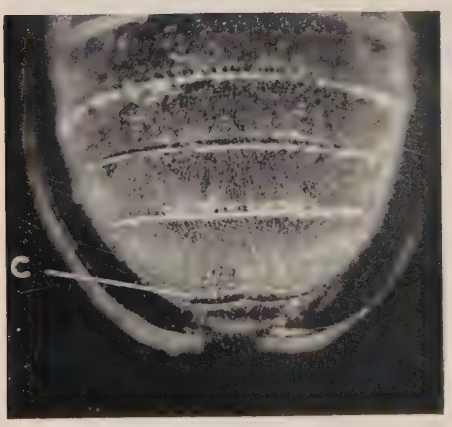
PLATE 6



Attack on Douglas fir by *Hylecoetus dermestoides*. White bore dust produced by the larvae can be clearly seen on the surface of infested timber.

PLATE 7

Beetles on surface of infested wood (×2)



Male (×20)

Female (×20)

Abdomen in ventral view. Note posterior margin of terminal segment (*c*), notched in male, continuously curved in female.

The death-watch beetle : secondary sex characters.

PLATE 8

moderately difficult to impregnate and this is a handicap to their utilization where preservation may be required. A number of round matched samples of each of these species obtained from freshly felled material have been put in the pond and are being removed at intervals and seasoned to compare their resistance to impregnation with that of samples which were seasoned immediately after cutting. So far only one group of Sitka spruce has been examined. These had been soaked for three months and then air dried and, when end sealed and impregnated with preservative under pressure, absorbed about double the amount taken up by matched unsoaked controls treated at the same time. This suggests that soaking also increases the permeability of the sapwood of resistant species although the action may be slower than with pine.

MYCOLOGY

CULTURE COLLECTION

During routine sub-culturing of the collection the condition of the cultures has been critically examined and a number of enfeebled strains have been rejected. Twelve new strains have been added to the collection and a revised catalogue has been prepared. A duplicate collection maintained under mineral oil for eight years has been sub-cultured; only five out of 490 cultures failed to grow and a number of oiled strains were more vigorous than comparable strains which had been regularly sub-cultured at three-monthly intervals.

One hundred and fifty cultures were supplied to other research workers and firms and complete duplicate sets, surplus after sub-culturing, have twice been made available to Professor Jones of Oxford University for examination to determine the extent of production of polyacetylene derivatives.

Cultures and fungus fruit bodies have been received for identification from the Rubber Research Institute of Malaya, the Forest Department, Kenya, and a number of British Universities and firms.

Using a technique, described by Tamblyn and Da Costa[24], recognizable fruit bodies have been obtained in 13 out of 22 Basidiomycetes examined. Use of this method has permitted the identification of the hitherto sterile fungus associated with the alder wood wasp (*Xiphydria camellus*) as *Daldinia concentrica*, following successful production of sporophores.

PHYSIOLOGY OF WOOD-ROTTING FUNGI

In collaboration with the Forestry Commission, tests are being carried out to determine how long *Fomes annosus* can remain alive in sawn timber after it has been air dried. Information on this point had been sought by a Colonial Forestry Department who were concerned about the possibility of infection being introduced in packing cases made from timber sawn out of trees containing butt rot caused by *Fomes annosus*.

SOFT ROT INVESTIGATIONS

A paper describing the results of investigations of the chemical effects of *Chaetomium globosum* on beech wood has now been published[25].

A further example of soft rot causing decay in a standing tree (sapele from Ghana) has been recorded. The presence of soft rot has been confirmed in the surface of samples of piling from Lake Victoria, East Africa, which had been attacked by larvae of the mayfly, *Povilla adusta*. It is thought probable that softening of the wood by the decay is an essential preliminary to attack by this insect.

The cellulolytic fungi *Myrothecium verrucaria* and *Memnoniella echinata*, both widely employed in laboratory tests of rot-proofed fabrics, have been shown to attack beech in pure culture. A series of isolations of fungi have been made from pieces of beech placed as "bait" in various soils. It was hoped that by growing the fungi from the bait blocks on to a medium containing nutrient salts with cellulose as the sole carbon source, active cellulose-destroying species would be selectively isolated. However, a number of fungi commonly isolated in this way, *Trichoderma viride*, *Fusarium* sp., *Actinomucor repens* and other Mucoraceous spp. have been shown incapable of attacking wood in pure culture. On the other hand, use of this method has yielded isolations of *Stachybotrys atra*, *Sporocybe* sp., *Sordaria* sp. and *Gelasinospora* sp., all of which actively attack beech wood in pure culture in the presence of nutrient salts. Species of *Chaetomium* and *Stysanus*, already known as soft rot fungi, have also been frequently isolated. The results of these isolations from soil indicate that *Trichoderma viride*, Mucoraceous spp. and *Chaetomium globosum* quickly colonize susceptible wood buried in the soil. Although *Trichoderma viride* is known to produce antibiotic compounds, it has been shown in pure culture experiments that its presence does not markedly reduce the ability of *C. globosum* to attack wood.

Half-centimetre thick blocks of beech have now been exposed hanging freely for 3 years in the 90 per cent humidity room at an equilibrium moisture content of 22·5 per cent. They show soft rot throughout their thickness and have lost up to 20 per cent of their original dry weight. Weight losses of blocks maintained at 21·5 per cent moisture content for the same period are barely significant and it is not likely that appreciable soft rot would occur at lower moisture contents than this. Similar beech blocks submerged under water out of doors for three years are also attacked by soft rot fungi and have lost 12 per cent of their original dry weight, but the soft rot has not yet penetrated throughout their thickness.

Examination of field test stakes as they fail, in order to assess the nature of the decay present in them, has continued. In both hardwoods and softwoods the part played by soft rot in causing failure appears to be considerable.

ROT IN COOLING TOWERS

Basidiomycete decay was originally reported as a major cause of timber failures in water-cooling towers in the U.S.A. but was considered unimportant in this country. However, since 1950 cooling towers of American design incorporating mist eliminators above the point at which water enters the tower have been built in the United Kingdom and mist eliminators have been installed in British natural draught towers. It has now been found that severe Basidiomycete decay is taking place in the mist eliminators. Extensive decay by *Poria nigrescens* in western red cedar and by *Gloeocystidium lactescens* in Scots pine have been observed. The latter fungus is of interest as it has previously been recorded only from hardwoods. The optimum growth temperature of *G. lactescens* is about 28°C, which corresponds with conditions prevailing in the tower from which it was isolated. Experiments to determine the capacity of the fungus to decay wood in pure culture are in progress.

LABORATORY TESTS OF WOOD PRESERVATIVES

No new tests of wood preservatives have been inaugurated during the year but a considerable number of tests that had already been started have been completed. Standard laboratory tests have been carried out on three

proprietary preservatives and a dip test on a solution of copper linoleate in white spirit.

Tests to determine the residual toxicity of surface treatments with various preservatives after long periods of exposure to the air under conditions simulating those in a roof (Annual Report for 1957, p. 29) have been continued. Treatments with creosote, 4 per cent sodium pentachlorophenate and 5 per cent sodium orthophenyl-phenate remain effective after 18 months' exposure, but pure α-monochlornaphthalene and an emulsion incorporating 4 per cent pentachlorophenol, though initially effective, are showing indications of failure after 18 and 14 months' exposure, respectively.

The toxic limits against *Chaetomium globosum* of creosote, copper naphthenate, lauryl pentachlorophenate and pentachlorophenol have been established by the Abrams mycelial mat method. Studies on toxicity of creosote and copper naphthenate when in contact with soil show that whilst the concentration of copper naphthenate required to prevent attack of beech is similar whether sterilized soil infected with *C. globosum* or unsterilized soil is employed, much higher concentrations of creosote were required to give protection in the unsterilized soil. Indications have been obtained that *Sporocybe* sp. may be one of the organisms more tolerant of creosote than *C. globosum*.

In view of the suggested incorporation of *Poria monticola* as one of the test fungi in the revised British Standard test of the toxicity of wood preservatives (B.S. 838), toxic limits for three strains of this fungus have been determined.

LABORATORY TESTS OF NATURAL DURABILITY

On behalf of the Forestry Commission, comparative tests have been carried out on the natural resistance to decay of European and Japanese larch. Similar tests on 14 other timbers have been completed. Tests on greenheart undertaken for the Colonial Development Corporation (Annual Report for 1957, p. 30) have shown that the sapwood in this species may be up to three inches wide, which means that poles of up to nine inches top diameter might consist mainly of sapwood and in use would not give service comparable with that of creosoted Scots pine.

A report has been prepared and circulated on work carried out to determine the cause of premature failure of western red cedar seed boxes[26].

SAP-STAIN AND MOULD INVESTIGATIONS

A comprehensive review of recent work on sap-stain has been written for publication.

The conditions that influence the growth of *Lasiodiplodia theobromae*, which is the most important fungus causing sap-stain in tropical hardwoods, have been studied and its rate of growth in wood measured. At 22°C it was shown that the fungus can penetrate 15 cm along the grain in 12 days in horse-chestnut wood. Growth across the grain is much slower—only 4 cm penetration being observed in six weeks (see Plate 6). The survival of the fungus in dry wood kept at various relative humidities is being studied. The effect of staining caused by *L. theobromae* on the decay resistance and permeability of poplar wood has been examined. A paper describing the physiological investigations on the fungus has been prepared.

Pine logs felled during the warmer months of the year often become infected with sap-stain before they can be sawn up. A field experiment to determine the value of end treatments with fungicides has been started at the Laboratory in co-operation with the Forestry Commission. The ends of four-foot lengths cut

from freshly felled Scots pine trees have been treated with various formulations of pentachlorophenol, some of which included sealing materials to prevent end splitting. Batches of logs were piled on the ground at the edge of a small pine plantation at the end of March, June and September and the condition of the wood examined after three and six months' exposure. Infestation of some logs with the larvae of the pine shoot beetle, *Myelophilus piniperda*, has somewhat reduced the value of the treatments, for stain has been introduced by the insects' tunnelling in the bark.

Laboratory tests have been carried out to determine the effectiveness against sap-stain fungi of various boron compounds, both alone and in admixture with sodium pentachlorophenate.

The effect of prolonged steaming on the susceptibility of various timbers to moulds has been examined; it was found that some woods, in particular poplar, become mouldy much more easily after having been steamed, presumably because some of the complex polysaccharides are broken down into simpler ones more readily assimilated by the moulds.

A report summarizing information about conditions under which logs of Maracaibo boxwood become stained in this country has been written and circulated to interested parties[27].

ENTOMOLOGY

AMBROSIA (PINHOLE BORER) BEETLES

Oak Pinhole Borer (Platypus cylindrus)

Investigations carried out by a member of the Colonial Office West African Timber Borer Research Unit, stationed at Princes Risborough, on the biology and fungal relationships of this insect, referred to in Annual Reports for 1954–57, have been suspended following his resignation in March 1958. This work had been undertaken to supplement studies by the staff of the unit in Ghana and Nigeria to throw light on some of the more fundamental problems governing the susceptibility of logs to infestation by ambrosia beetles (Scolytidae and Platypodidae). The results obtained to date, are of particular importance for the contribution they make to knowledge of the food relations of these insects by detailed investigations on the ecology of the fungal flora in the insect galleries, upon which published data are few, and of the role of individual species, hitherto virtually unknown, in the nutrition of the insect.

The significance of the relationship of fungi and ambrosia beetles is not confined to nutritional requirements, but has an important practical bearing on degrade of timber through staining. The need for extended investigations on the factors determining the susceptibility or resistance of logs and trees to attack by these insects is underlined by exploratory experiments at Princes Risborough with extractives as attractants and repellents.

West African Investigations

Contact has been maintained with the unit in West Africa, of which the officer-in-charge and his deputy have spent time at the Laboratory, when on leave, to review programmes of work and discuss results.

Survey of Damage in Coniferous Forests, Argyll

Following reports from a sawmill in the Strachur district of damage by ambrosia beetles in spruce and other conifer thinnings from Benmore Forest, Argyll, a preliminary survey of Forestry Commission plantations in the Benmore,

Ardgarten, Glen Duror and Barcaldine Forests has been undertaken as part of a joint investigation with the Forestry Commission to determine the cause of the damage and to assess its extent and significance. Two insects were found to be responsible, *Trypodendron lineatum* (Scolytidae) and *Hylecoetus dermestoides* (Lymexylidae). Damage to stumps and a log of Douglas fir by *Hylecoetus dermestoides* is shown in Plate 7. Further work on the times of attack in relation to felling and extraction is being planned.

BUPRESTID BEETLES

Examination of a consignment of logs of *Khaya grandifoliola* at the Laboratory revealed extensive tunnelling by a forest insect which took place in the growing tree. Provisional identification shows the species responsible to be *Chrysaspis splendens* which has previously been recorded from *Khaya* spp. in West Africa. The attack, which becomes occluded by fresh growth, is difficult to detect in logs in the round but is responsible for severe degrade of the timber. It is not known to what extent this type of attack may be prevalent.

Lyctus POWDER-POST BEETLES

Egg-laying

A technique has been developed for the study of the eggs of *Lyctus brunneus* to avoid the time and labour required in detecting them by cutting up wood blocks with a hand razor. Small oak sapwood veneers have been cut at 200μ and attached in small groups—three per group is convenient for subsequent examination—to a glass plate by rubber bands. Egg-laying takes place in the veneers, which can subsequently be separated easily for direct examination of the eggs, cutting being entirely avoided.

Prevention of Infestation in Sawn Logs

Owing to the continuing absence of attack in the English oak boards, treated in May 1955 by a 10-second dip in emulsions of dieldrin and BHC at concentrations of 1 per cent and 0·5 per cent and of DDT at 2 per cent and 1 per cent, they have been re-exposed to infestation by *Lyctus* beetles (see Annual Reports for 1955, p. 39, and 1956, p. 37). Active infestation first noted in 1956 is still present in untreated control boards.

HOUSE LONGHORN BEETLE (*Hylotrupes bajulus*)

Occurrences

Infestations in the roofs of four houses, ranging from 20 to 60 years in age, have been found in a small town in south Middlesex, adjacent to areas in north Surrey where the insect has been known to be active for some years. Reports have been received of attacks (believed to be extinct) in several old houses in areas of London. Isolated active infestations have been reported in Berkshire (near the main areas of infestation in Surrey) and in Yorkshire in the floor boards of a house built in 1951: enquiries in these localities have revealed no further cases of attack. A five-year-old Surrey house was found to have its pine-wood parquet flooring extensively attacked—the first known case of its kind in this country. Active attack has been found in wireless relay posts (believed to have been in use previously as telegraph poles) in a town in Surrey in which infestations in buildings have previously been reported. Examination showed that the creosote had not completely penetrated the sapwood and, as a result of weathering, cracks had opened beyond the depth reached by the preservative,

and eggs of this species had been laid therein. On hatching, the larvae had worked mainly in the untreated sapwood, although in some cases where the heartwood had decayed, this was also attacked. Information on all cases of *Hylotrupes* attack known to this Laboratory has been circulated to local authorities in the areas with which they are concerned, and in some cases they have been able to add to the existing information.

Experimental Work

In an attempt to accelerate the rate of larval growth under laboratory conditions, larvae have been inserted into blocks of Scots pine sapwood impregnated with a 6 per cent aqueous solution of peptone. This may also result in more uniform larval growth and facilitate investigations into the physical factors affecting the development and length of life-cycle of this insect.

The effect on egg-laying, hatching and subsequent larval development by confining pairs of beetles on a mosaic of pine sapwood blocks treated two years previously with borax or with copper or zinc naphthenates is being investigated. It appears that the longevity and egg-laying abilities of the beetles are not affected; some eggs hatched and the "egg larvae" began to tunnel through the treated surfaces, but no information is yet available on their survival.

COMMON FURNITURE BEETLE (*Anobium punctatum*)

Behaviour and Life-history Studies

Further information on the length of the life-cycle under different conditions and from a range of materials has been obtained. In general, it appears that the life-cycle extends from three to eight (or perhaps more) years in its natural out-of-door habitat, but it has been reduced to nearly two years in birch plywood bonded with blood glue by subjecting the plywood to incubator conditions (22°C and 86 per cent relative humidity) for 20 months, followed by one month in a refrigerator and six months out-of-doors. It is of particular interest to compare the three-year life-cycles obtained, under out-of-door conditions, in beech heavily decayed, probably by *Ganoderma aplanatum*, and in a fruit body of this fungus, previously removed from its host prior to exposure for egg-laying, which shows that such material provides all the essential nutritional requirements.

No information is available on the effect of felling at different times of year on the nutritional suitability of wood for attack. A start has been made in investigating this problem by cutting small branches off a willow tree at monthly intervals and drying them quickly under laboratory conditions. A few blocks cut from this material have been exposed for egg-laying under incubator and out-of-door conditions.

An investigation into the comparative susceptibility of some home-grown hardwoods (apple, cherry and poplar) and softwoods (Corsican pine, noble fir, Norway spruce, Scots pine, silver fir and western hemlock) has been commenced under out-of-door conditions by exposing for egg-laying sections cut across the diameter of discs. Particulars of the sites and times of felling are available, and in the case of the softwoods, detailed information on the densities and ring widths.

Effect of Fungal Decay and Blue-stain

Investigations have been continued on the effect of soft rot in beech upon its susceptibility to attack by common furniture beetle. Material decayed to low losses in weight (less than 7 per cent) exposed for egg-laying in 1956 has been cut up and it has been found that in the three zones of beech investigated and

under incubator conditions, larvae gain weight more rapidly in decayed blocks than in sound controls. Further matched samples exhibiting higher losses in weight have been exposed for egg-laying this summer.

Material for a fresh experiment involving comparison of the effects of decay by brown, white and soft rots of zoned samples of beech has been prepared and a few of the samples decayed by *Coniophora cerebella* and *Polystictus versicolor*, together with sound untreated controls, have been exposed for egg-laying. Fresh Scots pine sapwood has been inoculated with blue-stain (*Ceratocystis pilifera*) using a different technique from those previously employed in these studies, and some of the blocks have been exposed for egg-laying.

Effect of Steaming

Little information exists on the effect of steaming on the suitability of wood for attack by the common furniture beetle and previous experiments have not yielded consistent results. Material cut from a young birch tree and treated in a saturated atmosphere of water vapour at 48°C, 80°C and 100°C for different periods (one hour and 48 hours and, in the case of the first temperature, for two weeks also), and exposed for egg-laying in 1956, has been cut up for detailed examination. Treatments other than at 48°C for one hour rendered the wood less suitable for larval development assessed by the rate of gain in larval weight: treatments for 48 hours had a greater effect than for one hour and for two weeks at 48°C slightly greater than for 48 hours at this temperature. The percentage of larvae surviving in treated material, particularly after the longer periods, was lower than in the controls. In general, these results do not confirm earlier work with mature birch where it appeared that steaming a log increased the suitability of its wood (Annual Report for 1955, pp. 35–36). Since the earlier experiment was carried out on unmatched material from mature logs, unlike the present experiment where matched but immature material was used, the work is being repeated with samples cut from a single log of mature birch. The treatments chosen include ones used in steaming logs for peeling as well as furniture parts for bending and, in addition, exposure in a saturated atmosphere of water vapour at 80°C for one hour and at 100°C for one and a quarter or for three hours.

DEATH-WATCH BEETLE (*Xestobium rufovillosum*)

Biological and Behaviour Studies

Opportunity has been taken during the year of setting up at the Laboratory cultures of this species in naturally decayed oak and elm in order to supplement the supply of insects for use in experimental work and which to date have had to be obtained from infested buildings and willow trees, necessitating intensive search in the field.

The investigation started in 1957 (see Annual Report for 1957, p. 36) upon the effect of a range of moisture content on the rate of larval development in oak sapwood decayed to a known loss in weight by the white rot *Phellinus cryptarum* has been supplemented by a smaller experiment using beech decayed by the white rot *Polystictus versicolor*.

Studies of the behaviour of the beetles have included observations on the effect of temperature and light on mating and egg-laying and of the " tapping " characteristic of this wood-borer. Making use of the sound-detecting equipment, referred to on page 36 of this report, the tapping was presented on a cathode ray tube and photographed. This revealed that the sound is made by the insect knocking its head against the wood six to eight times in quick succession, the

intervals being about 105 milliseconds between each knock, with a tendency to accelerate to a 90 millisecond interval towards the end of the sequence. The tapping is not continuous but is apparently induced by suitable temperature or other conditions not fully understood. In addition, with the co-operation of the Photographic Section of the National Physical Laboratory, a slow motion film of the death-watch beetle has been taken to elucidate details of the movement of the insect before and during tapping. The National Committee on Biological Acoustics has been notified that these studies are in progress.

Secondary sex characters in the posterior margin and ratio of length to breadth of the terminal sternite (see Plate 8) have been detected, remedying a serious handicap in experimental work. A detailed description is being published.

Field Observations

(a) *King's College Chapel, Cambridge.* With the co-operation of the College authorities, data have been obtained on the numbers, distribution and sex ratio of death-watch beetles found in the roof space of the Chapel following emergence in 1958 and a comparison made with the number of fresh exit holes in the timbers. Tests with beetle " traps" were made for the first time but data on their value proved inconclusive. In addition to general information obtained for comparison with records of emergence from other infested buildings, resulting data provide a sound basis for the assessment of the efficiency of any control measures which may be carried out in the future.

(b) *H.M.S.* Victory. The numbers of beetles collected on H.M.S. *Victory* during the emergence season of 1958 was 74, thus the marked reduction following three fumigation treatments with methyl bromide in 1954–56 (see Annual Report for 1957, p. 36) was maintained. In view of these low figures and because of the large scale renovation and repairs which are still in progress, postponement of future fumigation was advised and was accepted by the Victory Advisory Technical Committee.

ELECTRICAL DETECTION OF ACTIVITY OF LARVAE OF WOOD-BORING INSECTS

An apparatus has been developed to detect and record on a chart sounds produced by insects within timber. It consists of:—

(1) A microphone attached to the infested wood within a thermostatically controlled sound-proof box, temperatures being recorded by thermocouples embedded in the timber.
(2) A pre-amplifier and main amplifier.
(3) A presentation unit with earphones to give audible recording, a cathode ray tube for visual perception, and a pen recorder to provide a permanent record.

At the present stage of development, amplification is limited by the effectiveness of the sound insulation within the box to a voltage gain of 3×10^5. This gain is sufficient to record sounds made by a single larva of the powder-post beetle, *Lyctus brunneus*, and to detect a number of sounds of varying intensity made by the much larger larva of the house longhorn beetle. These variations probably represent differences between larval movement and actual gnawing of the wood. Records kept continuously for a week did not reveal any apparent cycle of feeding, the bursts of activity occurring at irregular intervals frequently separated by periods of almost complete quiescence for several hours at a time. In cold weather activity is reduced and is no longer detectable at temperatures

below 17°C, but with a rise in temperature, activity is resumed immediately. Following handling of timber containing larvae of the house longhorn beetle, activity ceases for periods of half to one hour.

TOXICITY OF METHYL BROMIDE TO WOOD-BORING INSECTS

Laboratory experiments have been continued in co-operation with the Pest Infestation Laboratory, where the treatments were carried out, subsequent examinations being made at this Laboratory.

Death-watch Beetle

Previous tests with adults showed that a dose, expressed as a concentration-time product (C.T.), of approximately 100 mg h/l results in 100 per cent mortality in three days. The beetles used were of unknown age and treated about the time of egg-laying. At dosages below C.T. 100 a few viable eggs were laid between treatment and death. These tests have been repeated using adults of known age and dosed at C.T.s of 50, 60 and 70 shortly after mating but well before the time of egg-laying. The treated beetles lived for long periods, e.g. up to 37 days, before 100 per cent mortality was reached, compared with 67 days for untreated beetles, but egg-laying was completely prevented although many beetles showed no gross toxic effects from the treatment.

Common Furniture Beetle

Observations following fumigation in the spring of 1957 of plywood meter boards containing pupae and larvae of this species at dosages of C.T. 100 have been continued. Emergence of beetles in 1957, derived from the pupae, was prevented. Slight emergence from the same boards of beetles derived from the larvae occurred a year later (1958) at dosages of C.T. 100 and 130 but not at 190, indicating that larvae are more resistant than pupae.

Two further series of meter boards have been treated, the first series during the winter 1957–58 when larvae only were present, and the second in early summer 1958 when both larvae and pupae were present. Emergence of beetles from the boards treated in winter, i.e. derived from larvae, was completely prevented at all dosages ranging from C.T. 70–130 in contrast to the 1957 treatments. These anomalous results may be due to the variable condition of the meter boards used throughout the tests but, on the other hand, may well indicate that fully grown larvae, which would have pupated shortly, are less resistant than younger larvae. Separate observations on larvae extracted from the boards shortly after treatment showed that although some larvae were still alive 50 days after treatment at all dosages, percentage mortality was generally proportional to dosage level. Further observation on emergence of beetles from these boards in 1959 may well result in closer agreement of results and assessment of lethal dosages needed to arrest larval development.

Data from the second series of boards treated in early summer, i.e. when pupae were present, agree fairly closely with the results of the 1957 experiments but slight emergence of beetles recurred at a C.T. 100, a dose thought to be lethal to pupae. Further tests will be needed before the lethal dose for this stage is more precisely determined.

LABORATORY TESTS OF WOOD PRESERVATIVES AND INSECTICIDES

Contact Insecticides

A further series of tests, including much shorter periods of exposure than those given in last year's Report (pp. 37–38) has been carried out, exposing

wood-boring beetles to known deposits of aldrin, dieldrin or lindane on filter papers before transfer to untreated blocks for egg-laying.

These tests have shown that doses of contact insecticides sufficient to affect either death-watch or common furniture beetles will prevent egg-laying by them, although death of the beetles may be delayed for some days.

Complete results of these tests are not yet available, but it has been shown that with deposits of lindane at 0·02 mg/ sq. cm, an exposure period of 15 minutes or more is sufficient to prevent egg-laying by the common furniture beetle, whereas an exposure period of five minutes is not effective.

Preliminary tests are also being carried out with *Lyctus brunneus* and *Minthea rugicollis*.

Insecticidal Smokes

Following 12 months' storage, beetles have laid eggs this summer after emerging from *Anobium*-infested birch plywood exposed in a room where lindane/dieldrin or lindane/DDT smokes had been liberated immediately before the emergence period of 1957. In 1957, however, the former treatment had then prevented egg-laying by beetles emerging that summer, but the latter treatment had not done so.

Insecticidal Treatment of Anobium-*infested Birch Plywood*

A test has been carried out with a number of solutions of insecticides in white spirit for the eradication of the common furniture beetle in birch plywood.

For each insecticide, two boards of half-inch plywood were used. Each of these boards was sawn in half and one half brush-coated with insecticide on all surfaces, the other half being left untreated as a control.

Treatments were applied at the beginning of the emergence period in 1957, when the adults and pupae would be near the surface, thus accounting for the high proportion of control obtained that year. In Table 6 the measure of control is expressed as a percentage of the difference in numbers of exit holes as follows:

$$\frac{\text{Untreated} - \text{Treated}}{\text{Untreated}} \times 100$$

Table 6

Emergence of common furniture beetles from infested plywood

Treatment	1957			1958		
	Treated	Untreated	Control percentage	Treated	Untreated	Control percentage
0·5 per cent dieldrin	0	17	100	0	22	100
Orthodichlorobenzene	5	82	94	1	25	96
0·5 per cent BHC	0	187	100	2	45	95
20 per cent dichloro-ethyl-ether	3	104	98	2	32	94
5 per cent copper naphthenate	0	184	100	4	59	93
Paraffin	0	214	100	7	58	88
5 per cent zinc naphthenate	0	58	100	9	55	84
5 per cent pentachlorophenol with 5 per cent trixylenyl phosphate	0	85	100	21	75	72
White spirit	0	58	100	14	47	70
5 per cent pentachlorophenol with 7 per cent dehydrated castor oil	0	73	100	15	21	33
5 per cent sodium pentachlorophenate in water	108	211	49	264	203	0

GAMMA RAY TREATMENTS

Work has been continued on the effect of gamma radiation on three species of wood-boring insects in co-operation with the Radiation Chemistry Group, Atomic Energy Research Establishment, Harwell. A joint experiment with the Technological Irradiation Group of the Isotope Division, Atomic Energy Research Establishment, Wantage, has been planned, and a sectional block of Scots pine constructed at the Laboratory, in order to investigate the attenuation of gamma rays in wood in a range of thicknesses with particular reference to dosage requirements for the control of wood-boring insects.

Common Furniture Beetle

Confirmation has been obtained that the dosage required to prevent eggs from hatching depends on their stage of development. For example, under out-of-door conditions, eggs three to five days old were sterilized by treatment at 4000 roentgens (r), whereas eggs 25 days old, with embryos approaching maturity, hatched after irradiation at 96 000 r.

Irradiation of experimental samples containing inserted larvae at 6000 r did not prevent completion of larval development, pupation and emergence, whereas no emergence occurred after irradiation at 8000 r. Cutting up some of this material has shown that the proportion of dead pupae in blocks irradiated at 6000 r and 8000 r was higher than in those irradiated at lower dosages and in the controls, thus indicating that the effects of irradiation of larvae may be delayed until development has progressed as far as the pupal stage. Further evidence that treatment of larvae at a dosage of 8000 r will prevent emergence has been obtained by irradiating naturally infested meter boards this spring prior to pupation.

Pupae appear to be less resistant than immature adults, but insufficient data were obtained from material exposed in 1957 to compare the susceptibility of immature and mature beetles. Data on irradiation of mature adults of both sexes at 8000 r before mating show that although eggs were laid, none were viable. A fresh series of experiments has been carried out in 1958, covering treatment of pupae of both sexes and of immature and mature adults. Treated beetles of both sexes were mated together or with untreated individuals of the opposite sex with the object of comparing the susceptibility of the different sexes and of determining the effect on egg-laying and viability: results are not yet available.

Death-watch Beetle

Irradiation of eggs 26–31 days old has been carried out at dosages of 100 000 r, 150 000 r and 200 000 r, all of which prevented hatching: as the incubation period of the controls varied between 36 and 44 days, it is probable that the irradiated eggs were at a less advanced stage of development than those treated last year at 80 000 r when 8 per cent hatched.

Treatment of decayed oak blocks into which larvae of varying sizes, including fully grown ones, had been inserted during the winter 1956–57, at 6000 r prevented emergence, and this result has been confirmed by absence of emergence this summer from naturally infested elm and willow containing larvae at the time of irradiation in January 1957, at dosages between 5800 r and 7800 r. In both experiments beetles emerged from the control samples, mated and laid viable eggs.

No data are yet available on pupae but decayed oak blocks containing pupae have been treated this autumn.

Further studies have been made on the effect of irradiation on immature and mature adults. Data obtained for immature adults approximately half way through their hibernation period at the time of treatment (see Annual Report for 1957, p. 38), have now been analysed statistically and the apparent greater susceptibility of males as compared with females shown not to be significant. This investigation has been extended to provide data from immature adults irradiated at an earlier stage of hibernation at dosages ranging from 6000 r to 15 000 r. In this new experiment both sexes were treated and either mated together or with untreated individuals of the opposite sex. Preliminary results show that eggs laid by beetles when both sexes had been irradiated at 10 000 r and then mated together did not hatch. Results of mating treated and untreated sexes are not yet available. Evidence in support of these results was obtained by irradiating during the winters 1956–57 and 1957–58 immature beetles *in situ* in naturally infested elm and willow: treatment at dosages between 5800 r and 10 000 r did not prevent emergence of beetles and egg-laying during the following springs, but although a high proportion of the eggs hatched in the controls, less than 4 per cent of the eggs laid by beetles treated at dosages up to 7800 hatched and from which larvae were still alive and boring when examined six months later. At 10 000 r preliminary results show that no eggs hatched.

Lyctus *Powder-post Beetles*

Irradiation of larvae at different stages of development has shown that small larvae are more easily affected than larger ones: for example, under culture conditions (25°C and 75 per cent relative humidity), few beetles emerged from oak sapwood containing larvae up to three days old irradiated at 4000 r and none at 6000 r; larvae approximately 20 per cent grown treated at 4000 r yielded greater numbers of adults, but none emerged after treatment at 6000 r. For larvae approximately half to two-thirds grown a dosage of 8000 r was required to prevent emergence.

Studies have been carried out on the possibility of inheritance of sterility in future generations after irradiation of blocks containing larvae approximately half to two-thirds grown at a dosage of 4000 r which, at that stage of larval development, permits of the emergence of a reduced number of adults but sufficient for future breeding. It appears that there is a reduction in fertility of the adults which do emerge (P1 generation) resulting in a reduced F1 generation, but that this may not continue into the F2 generation. Further studies of the F2 generation on a larger scale are desirable.

STERILIZATION OF INSECT-INFESTED WOOD BY MEANS OF HIGH-FREQUENCY HEATING

A report has been prepared for publication on the studies undertaken in co-operation with the Laboratory of the Electrical Research Association at Leatherhead.

CHEMISTRY

WOOD EXTRACTIVES

Indian Rosewood (Dalbergia latifolia)

Studies on the crystalline phenolic substance isolated from this wood (see Annual Report for 1957, p. 40) have been continued in collaboration with the Department of Chemistry, University of Edinburgh. Progress has been made towards elucidation of the structure of the substance but the work is not yet complete.

Dihydroflavonols Present in Timbers of the Family Moraceae

The small dihydroflavonol group of substances has been found to be of widespread occurrence in Nature. Much attention has been given to these materials during the past few years and compounds of this type have been identified in many hardwood and softwood species. The isolation of dihydromorin from *Morus lactea*[28] provided the first evidence for the presence of dihydroflavonols in timbers of the family Moraceae, although the presence of the flavonol, morin, had been reported in some of these timbers. No morin could be detected in the heartwood of *Morus lactea* in its natural condition, though it was shown that it can readily be formed from the dihydromorin present by steaming the wood. This suggested the possibility that some or all of the morin stated to be present in other timbers of this family might have been produced artificially from dihydromorin during extraction and subsequent treatment. It was decided, therefore, to re-investigate some of these timbers, using mild conditions of extraction to minimize the conversion of dihydroflavonol to flavonol. The heartwood of the following timbers was examined:

(1) *East African Mulberry* (Morus lactea). The dihydromorin previously isolated from this timber appeared, at the time, to be a pure product, but subsequent investigation on the paper chromatogram using the chloroform-ethanol-water solvents of Brewerton[29] revealed the presence of small amounts of a second phenolic substance. This impurity was separated on a column of cellulose and identified as dihydrokaempferol. No other dihydroflavonols could be detected. A paper describing these results has been published[30].

(2) *Fustic* (Chlorophora tinctoria). Extraction of the wood with ether gave a product which was separated into water-soluble and insoluble fractions. The insoluble portion, obtained in good yield, was shown to be mainly morin (m.p. 294–5°C, not depressed on admixture with an authentic specimen; pentamethyl ether, m.p. and mixed m.p. 156°C). The soluble fraction was partitioned on a column of cellulose to give three main components, identified by melting point and mixed melting point and preparation of derivatives: (*a*) maclurin, m.p. 222–4°C, previously reported to be present in this wood, (*b*) dihydromorin, m.p. 226°C (penta-acetate m.p. 192°C), (*c*) (impure) dihydrokaempferol, m.p. 215–7°C (acetate, m.p. 118°C). Examination of the timber by Pachéco's method[31] revealed the presence also of small amounts of dihydroquercetin.

(3) *Mulberry* (Morus alba). This wood has been examined by several workers and morin, maclurin, 2: 4: 6: 4′-tetrahydroxybenzophenone and cudranin have been reported to be present. In the present investigation no morin could be identified, but paper chromatography has indicated the presence of dihydromorin and dihydrokaempferol. Further, Pachéco's method has shown the presence of small amounts of dihydroquercetin. Experiments are in progress with a view to isolating sufficient quantities of these materials for positive identification.

Cudranin (m.p. 198°C), the constitution of which is as yet unknown, was readily isolated in good yield. While the m.p. of this material and of its acetate (139–40°C) compare well with the values found by Suzushino[32], the product was shown to be a mixture and to give rise to a number of different spots on the chromatogram; at least one of these components was readily formed from the others.

The presence of maclurin or of tetrahydroxybenzophenone has not been confirmed as yet.

(4) *Jak-wood* (Artocarpus integrifolia). Ether extraction of this wood failed to bring out any appreciable quantities of dihydroflavonols, but extraction with acetone or methanol yielded small amounts of these compounds, tentatively identified on the chromatogram as dihydromorin and dihydrokaempferol. No dihydroquercetin could be identified in this instance by Pachéco's method.

(5) *Osage Orange* (Maclura pomifera). Investigation of this timber by Pachéco's method indicated the presence of dihydromorin, dihydrokaempferol and dihydroquercetin.

Thus, dihydromorin and dihydrokaempferol appear to be present in each of the five timbers examined, while dihydroquercetin occurs in at least three of them. Morin, on the other hand, was only identified positively in *Chlorophora tinctoria*.

DEVELOPMENT OF ACIDITY IN WOOD UNDER MOIST CONDITIONS

Samples of oak, beech, birch, Douglas fir and Sitka spruce have now been stored in sealed containers for two years at 48°C and 100 per cent relative humidity and the rate of development of free acid has been followed. The volatile component, which comprised 80 to 90 per cent of the total free acid, has been identified as acetic acid by paper chromatography and by the preparation of crystalline derivatives. For four of the species examined an exact correlation has been obtained between the amount of acetic acid extracted and the loss of acetyl groups in the wood as shown by analysis of the original woods and the residues. It thus appears that the acetic acid arises through slow hydrolysis of the acetyl groups under moist conditions. During the period of two years, under the conditions chosen for the experiment, approximately 70 per cent of the total acetyl groups were converted to free acid in Douglas fir and Sitka spruce and 50 per cent in beech and birch. From the results of other experiments carried out on small blocks of birch it has been shown that the rate of hydrolysis increased very considerably with increase in temperature.

The inhibiting effect of certain fungi on the production of free acetic acid in damp wood has been confirmed on a series of samples of obeche. Samples stored for six months at 48°C and 100 per cent relative humidity, found to be contaminated with growths of *Thermoascus aurantiacus* and *Monatospera lanuginosa*, contained no free acid. Similar samples, protected with mercuric chloride (1 part per 1000 parts total moisture), liberated acid equivalent in amount to approximately 0·5 per cent of the wood during the six month period and were entirely free from fungi. A similar result was obtained in treated and untreated samples stored at 25°C. In this instance the inhibiting fungus was found to be *Aspergillus fumigatus*. Free acid produced in this series was not measured quantitatively but its presence was indicated by the degree of corrosion of cadmium-plated test strips suspended in the enclosed air spaces over the wood samples.

PRODUCTION OF HARDBOARD FROM TROPICAL TIMBERS

Board-making trials have been carried out on mugongo (*Ricinodendron rautanenii*) from Northern Rhodesia, and on Caribbean pitch pine (*Pinus caribaea*) from British Honduras.

(a) *Mugongo* (Ricinodendron rautanenii). Because of its very low density it was found possible to make useable pulp from this species by passing green chips directly through the Sprout Waldron disc mill without prior treatment of any kind. Coarse plates were used and water was fed to the mill so that the pulp

was ejected at approximately 7 per cent consistency. Rejects from wet screening through 0·040 in. slotted plates were passed again through the mill and returned to the pulp. In this way pulp yields of 90 per cent were obtained. Boards pressed directly from this pulp were slightly below B.S. 1142 : 1953 requirements for strength and their water absorption was high. It was found, however, that oil-tempering with small quantities of linseed oil enabled them to meet specifications both for strength and for water resistance. Tempering with 5 per cent of oil was sufficient to bring the qualities of the boards well within the specified limits for Super Hardboard.

Stronger boards were made from pulps which had been refined by further treatment in the disc refiner. Their water absorption was still too high, however, and it was necessary to incorporate small amounts of wax or oil to bring the boards within the required limits.

Further trials on this species were made by the Defibrator process using steam in the laboratory Defibrator at 150 Lb/in.^{2} pressure. Pulp made in this way was pressed, without further refining, into boards which had good strength properties, but it was still necessary to subject them to wax-sizing or oil-tempering to obtain the required properties of water resistance. Since some degree of water-proofing treatment was necessary even with the more refined pulps, no great practical advantage in the final boards was obtained either from the use of steam, as in the Defibrator process, or from the extra power consumed in refining wet-ground fibre. The simple process of wet-grinding green chips followed by oil-tempering produced boards to specification requirements and had the merit of high yield coupled with low power consumption and simplicity of operation. If applied on a large scale this procedure could dispense with some of the costly equipment usually required for hardboard manufacture.

(b) *Caribbean Pitch Pine* (Pinus caribaea). Tests have been made on a log of Caribbean pitch pine which contained approximately 25 per cent of highly resinous heartwood. The resin content of the heartwood was 22 per cent by weight, soluble in 1 : 2 alcohol-benzene mixture, and that of the sapwood was 0·5 to 2·0 per cent. Good quality hardboard was made by the Defibrator process from chips prepared from sapwood only as well as from a mixture of sapwood and heartwood in the proportion in which they occurred in the log. The unrefined pulp was pressed into boards, which had adequate strength but rather high water absorption. A heat treatment for two hours in circulating air at 180°C was effective in reducing the water absorption of the boards containing heartwood to a value acceptable for Standard Hardboard. Those made entirely from sapwood required the addition of some waterproofing agent. In both cases oil-tempering with 2 per cent linseed oil was sufficient to bring the boards into the Super Hardboard category. Refining of the coarse Defibrator pulp by treatment in the Sprout Waldron disc refiner enabled boards to be made which had increased strength and, in the case of sapwood, slightly improved water resistance to the extent that Standard Hardboard requirements could now be met by heat treatment alone.

A rather speckled appearance developed in some of the boards made from mixed chips containing heartwood. This was due to small fragments of solid resin in the pulp which were fused in the hot press and spread out on the surface of the board to form small dark patches. Apart from this, the presence of the highly resinous heartwood in the chips had very little effect on the properties of the boards finally produced. In large-scale operation it would be unlikely for the average resin content of the starting material to be as high as that of the

sapwood-heartwood mixture used in these experiments. If sawmill waste or forest thinnings were the source of raw material the proportion of heartwood, and, thus, the overall resin content, could be expected to be considerably less.

GENERAL

Analyses have been carried out on a number of specimens, in varying stages of deterioration, taken from a 600-year-old elm pile from the base of the Jewel Tower, Westminster. These have confirmed the rather limited information available from other sources concerning the changes taking place in wood that is buried underground for long periods. While parts of the pile had undergone extensive decomposition, primarily of the cellulose and associated polysaccharides leaving a residue consisting largely of lignin, other parts were in a remarkably sound condition and did not differ greatly in composition from normal elm wood.

Among the more interesting of the enquiries received was one as to the hydrogen content of resin-impregnated densified wood to be used as a shielding material in atomic energy establishments, the absorption of radiation being largely dependent upon the hydrogen content of the material. Another concerned breakdown of beech spacer-blocks in a transformer of the North of Scotland Hydroelectric Board. This was found to be caused by nitric acid which is most likely to have been formed from the nitrogen and oxygen of the air by electrical discharge.

A paper has been published on the destruction of the organic matter of wood and other materials by treatment with hydrogen peroxide and sulphuric acid[33].

PHYSICS

VIBRATION METHODS

(a) *Technique*

The technique used hitherto at the Laboratory for detecting vibration response of wooden specimens has involved fixing a small iron plate to the specimen ; any movement of the plate relative to the magnets of a nearby telephone receiver induces a voltage in the coils of the latter, and this voltage is amplified and applied to a cathode ray oscilloscope. Recently, vibration strain gauges made of polarized barium titanate ceramic have become available, and their performance on wooden specimens has been compared with that of the telephone receiver. They are more sensitive than the receiver at the higher audio frequencies (above about 5000 c/s) but less sensitive below this limit. Although it would probably be possible to redesign some of the circuits in the apparatus so as to improve the performance of the ceramic gauges at low frequencies, they are not so convenient in practice as the telephone receiver, and in any future work on vibration, they will only be used in preference to the latter if special circumstances justify this course.

(b) *Correction of Vibration Measurements for Occurrence of Shear*

As mentioned in previous Reports, the frequency of vibration of beams in bending vibration is lowered by the occurrence of shear deformation, and in extreme cases the observed frequency may be less than half that expected when shear is neglected. The correction factor involves a quantity known as the shear deflection coefficient which has a value of 1 if the shear strain is uniform throughout the depth of the cross-section, and 1·2 if the shear strain is

distributed parabolically. Many attempts have been made to evaluate the coefficient theoretically, but there are considerable discrepancies among the theoretical estimates, even when the material is isotropic.

In view of the theoretical difficulties, an attempt has been made to estimate the coefficient experimentally. By analysing the vibration frequencies of a number of modes on a given specimen, it is possible to obtain E and sE/G, where s is the shear deflection coefficient, E the elasticity modulus and G the shear modulus. Evidently if G could be measured in adition to E, s could be obtained, and in the present experiments, G was measured by a torsional vibration method. The values of s derived in this way from experiments on brown sterculia, Sitka spruce, beech and ash varied between 0·96 and 1·14; the mean was 1·06 and the standard deviation 0·025. Some of the variability in s can be attributed to the variability of wood and to the difficulty of ensuring that all the experiments were carried out at the same moisture content. The mean value of s (1·06) is lower than many of the theoretical estimates, which, however, were made assuming the material to be isotropic. In the absence of an acceptable theoretical estimate for s, the experimental estimate is probably the best available at the present time.

(c) *Correlation Between Dynamic and Static Modulus of Elasticity*

During the course of the vibration work dynamic moduli of elasticity have been determined for brown sterculia, Sitka spruce, beech and ash. After the vibration measurements were completed, small strips were cut from the test beams and the moduli of elasticity determined by 4-point loading. Fourteen comparisons were made altogether; the average value of the ratio dynamic modulus/static modulus was 1·02, with a standard deviation of 0·10.

Measurements have also been made of the dynamic modulus and damping on fourteen 2 × 2 × 30 cm standard test specimens of ash. The static modulus was measured under centre loading; the average ratio dynamic/static was 1·07 with a standard deviation of 0·03. A rough calculation indicated, however, that the correction factor to the static moduli to allow for the shear deflection in centre loading was about 1·07, so that this comparison, as well as the one based on 4-point loading (where there is no additional shear deflection) indicates no difference between dynamic and static moduli in the grain direction.

(d) *Frequency of Vibration and Allied Properties of Plates*

Some years ago, theoretical work was carried out on the problem of calculating the critical buckling stress, the frequency of vibration and the deflection under load of plywood plates in terms of the elastic constants, dimensions and edge conditions, and an approximate method was developed which enabled estimates to be obtained for plates with all edges clamped or all supported. Since that time, workers elsewhere[34, 35] have made contributions which enable plywood plates with any combination of free, supported or clamped edges to be dealt with, and during the past year the calculations necessary for this development have been made at this Laboratory.

DIFFUSION OF WATER VAPOUR

Measurements have been completed of the rate of water vapour transmission through discs obtained from 20 consignments of Baltic redwood. There appears to be no systematic correlation between transmission rate and either locality of origin, ring width or density of the timber. The average values of the

transmission rates for all consignments (in 10^{-7} g/cm² cm sec for 100 per cent relative humidity difference) are:

Radial	Sapwood	2·04
	Heartwood	1·50
Tangential	Sapwood	1·89
	Heartwood	1·67

Previous results on a number of species indicated that the transmission rate was generally greater in the radial than in the tangential direction. This is true also for the sapwood in the present experiments, but not for the heartwood, for which the tangential transmission is greater.

The results of experiments on the change in moisture content with time of Corsican pine samples conditioned to equilibrium at one relative humidity and exposed at another have been re-examined, and some fresh results obtained. Assuming that the flow of water vapour is proportional to the moisture content gradient (Fick's law), and that the resistance to vapour transfer at the surface of the specimen is zero, the change in average moisture content should be described in the early stages of the process by the equation

$$\gamma = \frac{4}{l}\sqrt{\frac{Dt}{\pi}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and in the later stages by

$$1 - \gamma = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 Dt}{l^2}\right), \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where l is the thickness of the specimen, D is the diffusion coefficient for moisture in the wood and γ is the ratio of change in average moisture content at time t to total change in moisture content between the two humidities concerned.

One difficulty encountered in applying these equations is that the diffusion coefficient D varies with moisture content, and although many measurements pointing to this conclusion have been made, there is considerable conflict of evidence as to the nature of the variation[36].

Equation (1) suggests that a plot of γ against $\frac{\sqrt{t}}{l}$ should give a straight line independent of thickness in the early stages, and Fig. 5 shows that the prediction is verified for the results presented, although in one run out of the 14 so far completed, there appear to be systematic differences between the three thicknesses.

Fig. 5 also shows that the slope of the line, which is proportional to $\sqrt{D}$, changes from one humidity range to another, and even when the range is fixed, the slope differs as between desorption and adsorption conditions (Curves 1 and 2).

Using equations (1) and (2), estimates of the value of the diffusion coefficient D can be obtained, applicable respectively to the earlier and the later stages of the process. The diffusion coefficients obtained in this way are qualitative only, because of the variation in diffusion coefficient with moisture content, and because there are some discrepancies between theory and observation. In spite of the uncertainty as to their exact values the results suggest the following conclusions:

(i) the apparent diffusion coefficient in the adsorption process increases to a maximum at about 75 per cent relative humidity and then falls,

(ii) the diffusion coefficients in desorption are always greater than those in adsorption,

(iii) the diffusion coefficients calculated from equation (1) are always greater than those calculated from equation (2).

Summing up, it appears that equations (1) and (2), based on Fick's law, provide a useful guide to the preliminary interpretation of the results, but they do not account for all the observed features, and it is hoped to carry out further work in an attempt to improve the interpretation.

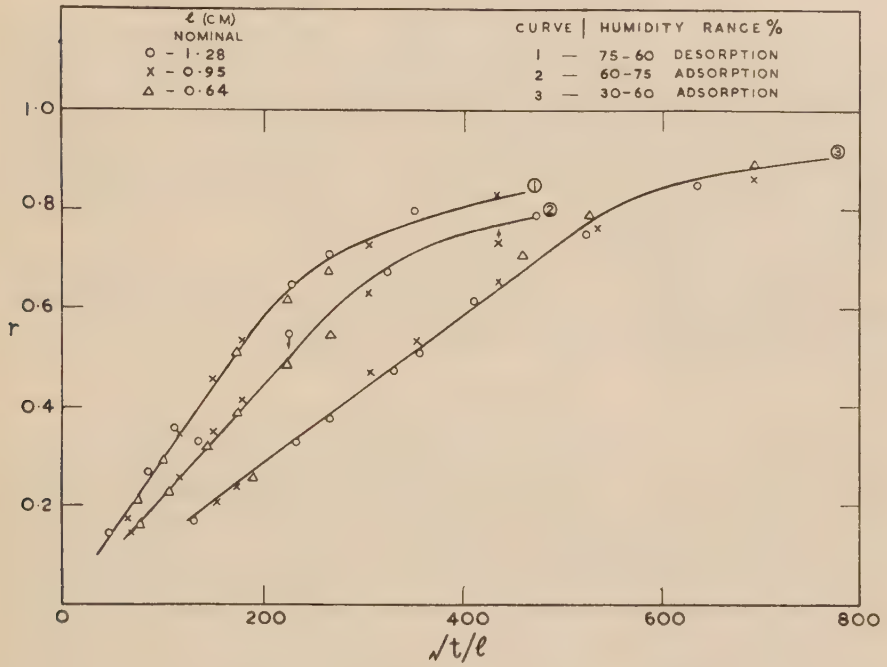


Fig. 5. Adsorption and desorption of water vapour by wood.

EXTERNAL RELATIONS

A total of 6199 cu. ft of timber was brought into the Laboratory during the year for experimental purposes. Of this quantity, there were 1957 cu. ft of imported hardwoods, mainly from British North Borneo and West Africa, 225 cu. ft of imported softwood, 1394 cu. ft of home-grown hardwoods and 2623 cu. ft of home-grown softwoods. This is 1902 cu. ft less than the amount brought in during the preceding year and this reduction has come mainly in the imported softwoods and hardwoods.

GENERAL TESTS

Reports on the general properties of the following timbers were completed and circulated:

White seraya (*Parashorea malaanonan* var. *tomentella*) from Borneo;
Light red seraya (*Shorea leptoclados*) from Borneo;
East African olive (*Olea hochstetteri*) from the Sudan.

General tests on the following timbers have been completed and reports are being prepared, viz. keruing (*Dipterocarpus caudiferus*) from North Borneo, and African mahogany (*Khaya anthotheca*) from Ghana.

Tests are proceeding on:

White seraya (*Parashorea malaanonan*) from North Borneo;

Dard red seraya (*Shorea pauciflora*) from North Borneo;

African mahogany (*Khaya grandifoliola*) from Nigeria.

A final consignment of red seraya (*Shorea waltoni*) has been received from North Borneo and the tests will be carried out as soon as possible.

TIMBER QUALITY IN RELATION TO SYLVICULTURE

The work carried out on conifer species in co-operation with the Forestry Commission, to determine the quality of home-grown timber and the effect of sylvicultural conditions on the timber produced, was continued during the year. Five consignments of 400 to 500 cu. ft each were brought in for testing in all sections and four consignments of five trees each for limited tests, chiefly stem analysis and strength tests. The species were, for general tests, Japanese larch, European larch, Corsican pine and Scots pine, and for limited tests, grand fir and western hemlock, noble fir and Norway spruce.

Six progress reports have been published on four species during the year, namely Serbian spruce, Douglas fir (two), Norway spruce (two) and Japanese larch. One other report, on Japanese larch, is in the press and one on European larch is in preparation.

STEM ANALYSIS

The work on stem analysis has been continued on all the conifers brought in for test and is almost completed on the timbers received to date. Of the nine consignments tested this year, final figures have been obtained on specific gravity, ring width, area increment, moisture content and percentage of heartwood throughout the trees from six consignments while the practical work on the other three has been completed and the final figures are now being prepared.

The Corsican pine, which was 54 years old, is of interest in that it is the first consignment of that species on which stem analysis has been carried out and that the average specific gravity curve for the butts of the five trees examined is higher than that of any consignment of any other softwood species tested. The range between individual trees is not large. It is not safe to assume, however, that the specific gravity of this species as a whole will be at the level of this consignment, since results show that in some of the other species there are appreciable differences according to site.

The Japanese larch is of interest because that from Tintern, 34 years old, gave almost as high a specific gravity as that from Ardchullary, which was nearly 20 years older, and the same specific gravity as the Greystoke material previously tested, which was 16 years older. In addition, the average rate of growth of the Tintern material was faster than either of the others, and it may be assumed that if it follows the same specific gravity pattern as the other two, the Tintern timber, age for age, will have a greater volume of high density material.

Results such as these have brought to light the need for further investigation of the factors affecting specific gravity. Both the Japanese larch results and those from the Corsican pine consignment, which had two trees of widely differing growth rates giving the same specific gravity, indicate that rate of growth in terms of the number of rings per inch does not always influence the specific gravity to as great an extent as other factors. One of these other factors, the percentage and density of the summer wood has been the subject of an investigation which is described below.

Results of the one consignment of European larch tested showed a rapid increase in specific gravity from the centre to the outside of each butt disc with no sign of levelling off although the timber was 48 years old. These results, like those on the Corsican pine, cannot be regarded as giving a typical specific gravity pattern for the species without confirmatory tests on consignments from other sites.

The pattern of specific gravity across the tree has been studied further with reference to earlier consignments and in the light of other research workers' findings on the presence of "juvenile wood" in the centre of some of the *Pinus* species abroad. Juvenile wood has been said to be associated with low specific gravity values for the early years of growth which become markedly higher where the normal wood begins. In the pines tested at the Laboratory, however, there is little evidence of this relatively sudden change to a more uniform specific gravity; the average specific gravity tended to increase steadily for at least 30 years of growth in the butt discs that were studied. In contrast to this, the trend in Sitka spruce discs showed a steady decrease in the specific gravity during the early years, and the higher value in the centre was not reached again during approximately the first 30 years of growth. The consignments of grand fir and western hemlock tested during the year showed a similar pattern at the butt to that of the Sitka spruce. Further investigation of these two species will be necessary to ascertain whether this pattern is typical.

In connexion with the problem of high specific gravity in the centre of the tree, preliminary investigations on the influence of resin on the specific gravity have been made during the year. Samples from the butts of two trees of Scots pine, three of Corsican pine, two of grand fir and three of Sitka spruce were de-resined and the specific gravity for each five years' growth was obtained and compared with matched samples which had not been de-resined. Results showed that where higher specific gravity values occur towards the centre of trees of Scots pine and Corsican pine, the increase can be attributed to the presence of resin and that resin occurs throughout the cross-section of the butt of some trees; but only towards the centre does it seriously affect the normal trend of the specific gravity curve. In Corsican pine it was found that two of the trees examined, which did not show a high specific gravity in the centre, had a very small quantity of resin which was evenly distributed throughout the cross-section but that the third had a heavy concentration around the pith giving an abnormally high specific gravity, the amount of resin decreasing with the distance from the centre. In Scots pine, both trees had a heavy concentration of resin in the centre where the specific gravity was high, with an even amount throughout the rest of the cross-section. In grand fir and Sitka spruce, however, no evidence of resin was found, resin-extracted samples giving substantially the same values as the control samples, that is, with a high value at the centre, dropping for some years before beginning to increase again.

STUDY OF DENSITY WITHIN INDIVIDUAL RINGS

During the year a project was started for a more detailed analysis of a single ring in softwoods and of the factors determining its density. These factors are the specific gravity of the summer wood and spring wood and the percentage present of each. For this work it was decided to study in detail European and Japanese larch, but other species were studied to a limited extent to help the investigation. The samples were from single rings selected at five-year intervals

across the radius of a disc in order to correlate with the samples used in the gross measurement of stem analysis of specific gravity. When the observed specific gravities of the separate summer wood and spring wood were combined according to the percentage of each present, a value was obtained for the specific gravity of the whole ring which was generally similar to that measured on a control sample of the whole ring. In the larches exceptions were recognized as containing a third zone of intermediate density wood, whereas in certain other species such as grand fir and Sitka spruce the intermediate zone is always present, and future work is proposed to measure the specific gravity of this zone.

Three consignments, already subject to general test, have so far been examined; these were one consignment of Japanese larch from central Scotland (Ardchullary) and another from South Wales (Tintern), with one consignment of European larch from the south of Scotland (New Abbey). Three trees from each parcel were examined at the butt, together with discs taken at 20 ft intervals up the tree from some of the trees.

In both species, the spring wood had an almost uniform specific gravity throughout a disc, and an average of about 0·270. The specific gravity of the summer wood varied considerably between individual rings, although that of rings in the early years of growth was generally lower than that of later growth. At the butt, the summer wood of Japanese larch had a range of specific gravity from 0·530 to 0·750, while that of European larch was appreciably denser throughout all periods of growth and ranged from 0·640 to 0·820.

While the specific gravity of the whole ring was statistically shown to be influenced to some extent by the variations in the specific gravity of the summer wood, a more significant correlation was obtained with the percentage of summer wood, which ranged from 20 to nearly 60 per cent in both species. The percentage summer wood in this material also was related closely to the number of rings per inch, rather than to the period of growth.

Comparing the two parcels of Japanese larch, at any one period of growth that from Ardchullary tended to have both less dense and a lower percentage of summer wood than the Tintern material. These differences are reflected in the closely similar overall specific gravities of the two consignments although the Ardchullary trees were 20 years older.

Three butt discs of European larch from Kent have been received for testing and it is hoped that the results will clarify differences already observed between the two species of larch.

Measurements of percentage summer wood have also been used to study the variation between trees of the consignment of Corsican pine from Thetford.

GRADING OF HOME-GROWN HARDWOODS

The Committee set up to prepare Grading Rules for home-grown hardwoods has now completed its work and the Rules are ready for publication.

TRADE SURVEYS

A report on the use of timbers in cooperage and the manufacture of vats and filter presses[37] and a survey of timbers used in road vehicles[38] have been issued.

VISITORS AND EDUCATION

Although the number of parties accepted at the Laboratory had to be restricted, the demand for visits has been slightly higher than in the preceding years.

Visits by individual foresters or persons from wood-using firms totalled 93, only six fewer than last year. The number of parties received was 17, an increase of four over the preceding year and the total number of persons shown round the Laboratory was 288. The increase in the number of parties is due to a greater increase in requests from other Government departments, from which nine parties were received as compared with five from the trade.

Visitors from overseas numbered 91, and they represented 38 countries.

The number of individual courses, lasting from ten days to two months, decreased; six officers, all from overseas, were accommodated.

Of the four forestry-teaching Universities, three sent their students for two days each, while Oxford University sent theirs for one day. The Imperial College of Science also sent their students for one day. The total number of visiting students, including post-graduates, was 115.

Four courses of instruction for kiln operators were held, the number of trainees being 39.

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F. Y. Henderson,
Director.

Forest Products Research Laboratory,
Princes Risborough,
Aylesbury, Bucks.
January, 1959.

APPENDIX I

STAFF OF THE FOREST PRODUCTS RESEARCH LABORATORY

31st *December*, 1958

Director of Forest Products Research: F. Y. Henderson, C.B.E., D.Sc., D.I.C.

ADMINISTRATION

Assistant Director: J. Bryan, M.Eng., A.M.I.C.E.
Senior Principal Scientific Officer: P. Harris, B.Sc.(Eng.), A.M.I.Mech.E.
Higher Executive Officer: R. D. Weeks, M.B.E.
Executive Officer: Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge); E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Senior Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officers: G. L. Franklin; D. G. Patterson, M.Sc.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, F.Inst.P. (Officer in Charge).
Experimental Officers: E. H. Adams; J. McC. Paton.

SECTION OF SEASONING

Principal Scientific Officer: W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers: R. E. Hodge, Assoc.I.Mech.E.; D. D. Johnston; G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Assistant Experimental Officer: R. H. Wynands.
Temporary Assistant Experimental Officer: D. C. Bedding.

SECTION OF TIMBER MECHANICS

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officers: A. J. Comben, B.Sc.; W. T. Curry; J. G. Sunley, M.Sc.
Senior Experimental Officer: A. J. Foord.
Experimental Officers: G. R. Brock; W. T. Hide.
Assistant Experimental Officers: S. A. Covington; Miss W. M. Fogerty.

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Principal Scientific Officer: D. N. R. Smith (Officer in Charge).
Experimental Officers: R. Cockcroft; Miss E. Lee; D. F. Purslow, B.Sc.; L. W. Redding.

SECTION OF CHEMISTRY

Principal Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Senior Scientific Officer: R. A. Laidlaw, B.Sc., Ph.D.
Senior Experimental Officer: D. F. Packman, B.E.M.
Experimental Officer: L. C. Pinion, B.Sc.
Temporary Assistant Experimental Officer: G. A. Smith.

SECTION OF MYCOLOGY

Principal Scientific Officer: J. G. Savory, B.Sc. (Officer in Charge).
Experimental Officer: E. C. Badcock.
Assistant Experimental Officer: Mrs. C. A. Savory, B.Sc.

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Principal Scientific Officer: J. D. Bletchly, B.A., B.Sc., F.R.E.S. (Officer in Charge).
Scientific Officer: M. G. White, M.A., F.R.E.S.
Senior Experimental Officer: E. C. Harris, F.R.E.S.
Experimental Officer: Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: K. J. S. Walker, M.A.
Senior Experimental Officers: H. J. Endersby; R. Goodchild.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer: F. G. O. Pearson, B.Sc. (Officer in Charge).
Senior Experimental Officer: A. V. Thomas, M.Eng.
Experimental Officer: Miss C. Webster.
Assistant Experimental Officer: Miss H. A. Fielding, B.A.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: J. F. S. Carruthers, B.Sc., A.M.I.Mech.E.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Experimental Officer: R. W. Hudson.
Assistant Experimental Officer: B. H. Paxton.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer: C. J. N. McCracken, B.A., Dip.For. (Officer in Charge).
Experimental Officer: J. A. H. Broughton, B.Sc.
Assistant Experimental Officer: T. Harding.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer: W. J. Baldwin.
Experimental Officer: E. A. Steel, Assoc.I.Mech.E.

APPENDIX II

LIST OF PUBLICATIONS ISSUED DURING 1958

A. STATIONERY OFFICE PUBLICATIONS

Forest Products Research, 1957.

Decay of Timber and Its Prevention. By K. St. G. Cartwright, M.A. and W. P. K. Findlay, D.Sc. (*Second Edition.*)

Bulletins:

No. 42 The Strength Properties of Plywood. Part 4. Working Stresses. By W. T. Curry.

No. 43 Experiments on the Treatment of Redwood Sapwood by Dipping. By D. F. Purslow, B.Sc.

Leaflets:

No. 11 The Hot and Cold Open-tank Method of Impregnating Timber. (*Revised Edition.*)

No. 14 The House Longhorn Beetle. (*Revised Edition.*)

No. 45 The Steam Bending Properties of Various Timbers. (*Revised Edition.*)

No. 47 The Movement of Timbers. (*Revised Edition.*)

Special Report:

No. 13 The Longitudinal Permeability of Some Hardwoods and Softwoods. By D. N. Smith and Eleanor Lee.

B. OTHER PUBLICATIONS

ARMSTRONG, F. H., and SAVORY, J. G. The Effect of Blue-stain on the Bending Strength and Other Mechanical Properties of Ramin, *Gonystylus* sp. *Emp. For. Rev.*, 1958, **37**(3), 352–354.

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APPENDIX III

REFERENCE LIST OF COMMON NAMES CITED IN TEXT

Abura	*Mitragyna ciliata*
African mahogany	*Khaya* spp.
Apple	*Malus sylvestris*
Ash	*Fraxinus* spp.
Ash, English	*Fraxinus excelsior*
Balsa	*Ochroma lagopus*
Baltic redwood	*Pinus sylvestris*
Beech	*Fagus sylvatica*
Birch	*Betula* spp.
Boxwood, Maracaibo	*Gossypiospermum praecox*
Brown sterculia	*Sterculia rhinopetala*
Caribbean pitch pine	*Pinus caribaea*
Cedar, Western red	*Thuja plicata*
Cherry	*Prunus avium*
Chestnut, Horse-	*Aesculus hippocastanum*
Corsican pine	*Pinus nigra* var. *calabrica*
Dark red seraya	*Shorea pauciflora*
Douglas fir	*Pseudotsuga taxifolia*
East African mulberry	*Morus lactea*
East African olive	*Olea hochstetteri*
Elm	*Ulmus* spp.
English ash	*Fraxinus excelsior*
English oak	*Quercus robur* and *Q. petraea*
European larch	*Larix decidua*
Fir, Douglas	*Pseudotsuga taxifolia*
Fir, Grand	*Abies grandis*
Fir, Noble	*Abies procera*
Fir, Silver	*Abies alba*
Fustic	*Chlorophora tinctoria*
Gaboon	*Aucoumea klaineana*
Grand fir	*Abies grandis*
Greenheart	*Ocotea rodiaei*
Hemlock, Western	*Tsuga heterophylla*
Hickory	*Carya* spp.
Horse-chestnut	*Aesculus hippocastanum*
Indian rosewood	*Dalbergia latifolia*
Iroko	*Chlorophora excelsa*

Jak-wood	*Artocarpus integrifolia*
Japanese larch	*Larix leptolepis*
Keruing	*Dipterocarpus* spp.
Larch, European	*Larix decidua*
Larch, Japanese	*Larix leptolepis*
Light red seraya	*Shorea* spp.
Mahogany, African	*Khaya* spp.
Maracaibo boxwood	*Gossypiospermum praecox*
Mugongo	*Ricinodendron rautanenii*
Mulberry	*Morus alba*
Mulberry, East African	*Morus lactea*
Noble fir	*Abies procera*
Norway spruce	*Picea abies*
Oak	*Quercus* spp.
Oak, English	*Quercus robur* and *Q. petraea*
Obeche	*Triplochiton scleroxylon*
Olive, East African	*Olea hochstetteri*
Osage orange	*Maclura pomifera*
Pine	*Pinus* spp.
Pine, Caribbean pitch	*Pinus caribaea*
Pine, Corsican	*Pinus nigra* var. *calabrica*
Pine, Scots	*Pinus sylvestris*
Poplar	*Populus* spp.
Ramin	*Gonystylus* spp.
Redwood	*Pinus sylvestris*
Redwood, Baltic	*Pinus sylvestris*
Rosewood, Indian	*Dalbergia latifolia*
Sapele	*Entandrophragma cylindricum*
Seraya, Dark red	*Shorea pauciflora*
Seraya, Light red	*Shorea* spp.
Seraya, White	*Parashorea malaanonan and P. malaanonan* var. *tomentella*
Scots pine	*Pinus sylvestris*
Serbian spruce	*Picea omorika*
Silver fir	*Abies alba*
Sitka spruce	*Picea sitchensis*
Spruce	*Picea* spp.
Spruce, Norway	*Picea abies*
Spruce, Serbian	*Picea omorika*
Spruce, Sitka	*Picea sitchensis*
Sterculia, Brown	*Sterculia rhinopetala*
Sycamore	*Acer pseudoplatanus*
Western hemlock	*Tsuga heterophylla*
Western red cedar	*Thuja plicata*
White seraya	*Parashorea malaanonan* and *P. malaanonan* var. *tomentella*
Willow	*Salix* spp.

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(75641) Wt. 3454/934 K.8 5/59 Hw.

Printed and published by
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Printed in Great Britain

S.O. Code No. 47-74-0-58